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ABSTRACT

This NCHSR research program in the application of computers in health care--conducted over the ten year span 1968-1978--identified two areas of application research, an inpatient care support system, and an outpatient care support system. Both of these systems were conceived as conceptual frameworks for a related network of projects and ideas that would eventually converge into a real information system. The description of the inpatient care support system includes use of computers in hospital information systems, clinical laboratory systems, radiology, electrocardiography, patient monitoring, and emergency medical care. The section on the outpatient care support system includes use of this technology in ambulatory medical record systems, the physican's office, and telemedicine. In addition, this report describes information support activities, including computerized databanks, computer-based consultation, special hardware, and specific projects aimed at transferring proven technologies to health care settings. A list of technology program projects supported by NCHSR and a selected bibliography are appended. (Author/RAO)

NCHSR

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Computer Applications in Health Care

Prepared by:
Medical Information Systems Cluster
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Foreword

This report documents ten years of medical care computer applications research by the National Center for Health Services Research (NCHSR), much of which resulted in beneficial innovations implemented into the health care system. What also has been achieved is a clearer and more realistic view of the potential of computers to address problems in the health area. We now know that computers can be gainfully used and will be accepted in some of the more obvious health applications at the institutional level, such as hospital information systems and ambulatory medical record systems. What lies ahead is to extend and expand this research experience in two directions. One direction is to explore the ways of aggregating the health service information available from computers at the institutional level, and making it available at the planning and resource allocation level. The other direction is to utilize the extensive clinical data bases that are becoming available as a result of computerization to improve the medical care process. These are challenging goals for NCHSR and ones that hold the promise of advantageously modifying the health system.

Gerald Rosenthal, Ph.D.
Director

June 1979

Summary

Program accomplishments

The efforts by the National Center for Health Services Research (NCHSR) in the application of computers in health care have resulted in a number of noteworthy accomplishments. Among these accomplishments are the demonstration and evaluation of a comprehensive hospital information system, the development and dissemination of a new medical computer language, the design of a commercially marketable automated ambulatory medical record system, the establishment of clinical databanks, and the development and release of a computer-assisted electrocardiogram analysis program.

A demonstration of the Technicon Corporation MIS-1 hospital information system at El Camino Hospital, Mountain View, California, and concurrent evaluation by Battelle Columbus Laboratories documented improved hospital operation. Benefits were realized in the improved quality of patient care and the increased productivity of the nursing staff following the implementation of the system.

The Massachusetts General Hospital Utility Multi Programming System (MUMPS) is a new computer language developed to meet the special needs of medical computing. MUMPS provides a common language for developing and exchanging medical programs. It has been accepted by the American National Standards Institute; has enthusiastic user groups in the United States, Europe, Japan, and South America; and is widely marketed by a number of computer companies.

The Computer Stored Ambulatory Medical Record (COSTAR) system was developed initially for use by the Harvard Community Health Plan. The success in that setting in terms of improved record keeping, more rational allocation of resources, and improved patient care led to the development of COSTAR V. This new system was designed to meet the needs of a variety of ambulatory medical care settings from large health maintenance organizations to small group practices.

Two clinical databanks were established and demonstrated, one at Duke University for coronary artery disease and the other at Stanford University for rheumatic diseases. These databanks make available aggregated, longitudinal clinical experience that significantly improves the ability of physicians to care for patients with these chronic diseases. A further benefit of databanks is that they make available data that allow a dynamic assessment of emerging medical technologies.

The Electrocardiogram Analysis (ECAN) program was developed and released for commercial use. This activity resulted not only in improving the quality of electrocardiogram analysis and increasing the productivity of cardiologists, but also contained the cost of this widely used medical service.

Current program

The current program of NCHSR as it applies to computers in health care has two major but related thrusts. The first is the development of an Inpatient Care Support System and the second, the development of an Outpatient Care Support System. The inpatient activities are the logical sequelae of the successful demonstration of a hospital information system (HIS) at El Camino Hospital. These include attempts to computerize nursing care plans and the medical audit function. Information on HIS characteristics will be developed that can serve hospital decision makers who are faced with the task of selecting and implementing such systems. The development, demonstration, and evaluation of the highly sophisticated Problem Oriented Medical Information System (PROMIS) is being carried out. PROMIS not only functions as a hospital information system but serves as a source of medical guidance and consultation to the physician as well. PROMIS facilitates access to medical knowledge and supports the user in diagnosis and therapy selection.

The outpatient program is closely related to the successful development of the COSTAR V system. COSTAR V is perceived as a vehicle that will provide entree to ambulatory care settings for additional computer application programs. Small automated laboratory devices, interactive patient history progams, patient education, and training functions currently are being considered in conjunction with COSTAR development. A wide range of consultation and guidance programs are in various stages of readiness. They ultimately will be tested in ambulatory care settings in the context of COSTAR V.

A number of Information Support Activities are identified. The most important of these is the establishment of databanks. Databanks in coronary artery disease and rheumatic diseases currently are being expanded and extended in attempts to determine their utility and acceptability to physician users. Ultimately, other diseases will be included in the databank effort. Other information support activities include development and testing of various consultation programs and the development of specialized hardware. Some typical computer-based consultation programs help the physician to select the correct antibiotic, restore the patient's electrolyte balance, and interpret laboratory results. A special hardware device was designed to make possible fast, accurate, reproducible measurement of X-ray angiogram images.

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Introduction

Since its inception in 1968, the National Center for Health Services Research (NCHSR) has been concerned with the development and application of computers in health care settings. In the course of this extended and continuous effort, some 150 grants and contracts were supported, resulting in numerous research reports, formal evaluations, state-of-the-art studies, surveys of the field, syntheses, user guidelines, and operational systems. These research projects reflect an attempt by the NCHSR to match technological solutions to the problems facing the Nation in the health area.

It has been observed (Tierney, 1978) that over the past 20 years the focus of Federal programs has shifted from access (Medicare, Medicaid, and training more physicians) to quality (establishment of Professional Standards Review Organizations—PSRO's) and most recently to cost (containment of inpatient hospital costs). It is not surprising then that similar shifts have occurred within the NCHSR research program. This report will review the accomplishments of NCHSR in the area of computer technology and present the current status of its program.

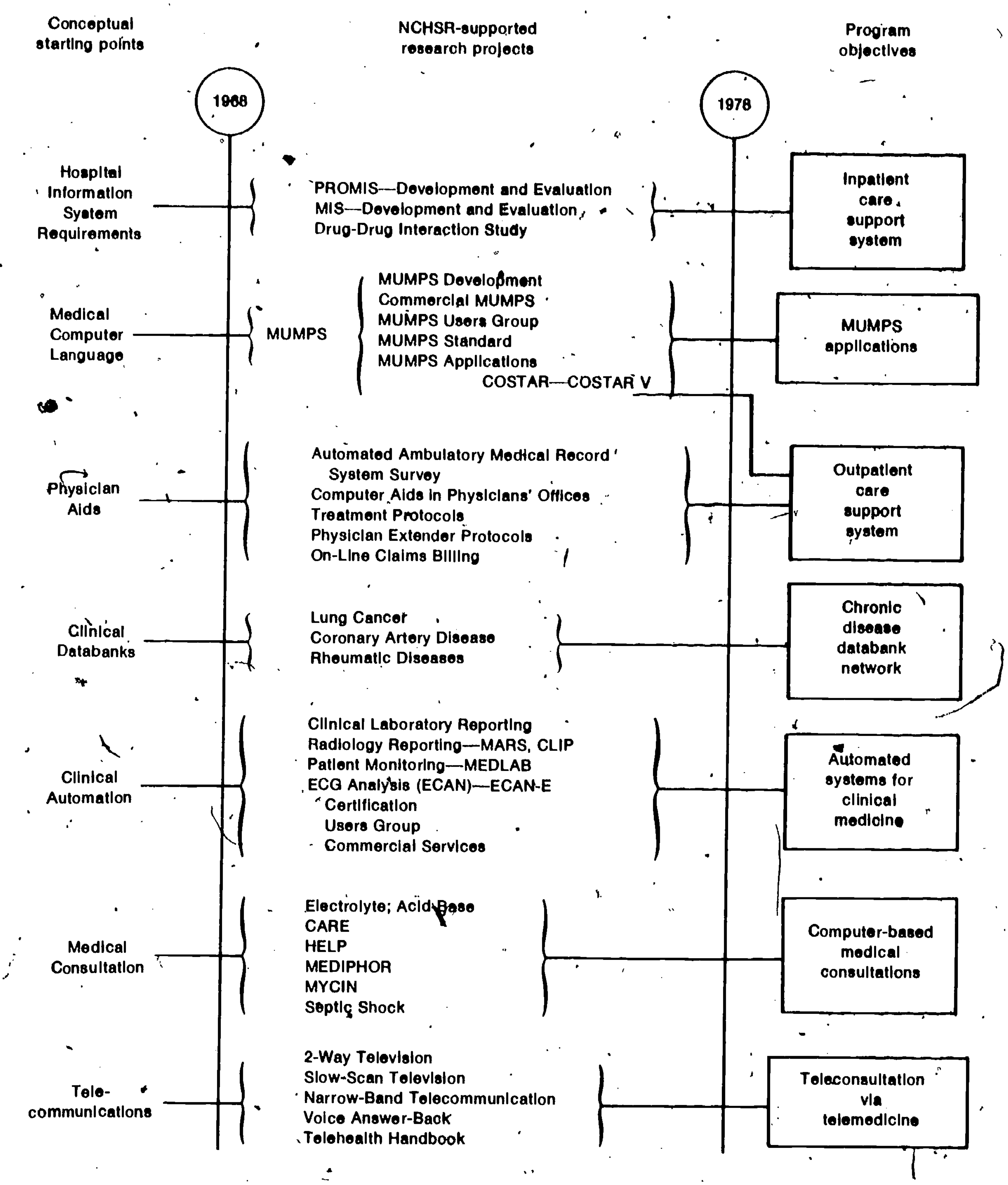
The application of computers in the health care system usually takes two forms. One form is capital substitution, where machinery is used to do a job formerly performed by people. This manpower-sparing application provides a potentially attractive economic trade-off since the cost of machinery usually declines with time whereas personnel costs tend to increase. The other form is the undertaking of tasks that previously were not feasible by manual methods. With the increasing power and sophistication of computer machinery, more and more complex and burdensome tasks in health care are being addressed by computers. The underlying rationale for the NCHSR program in computer technology is that the careful introduction of technology will facilitate and/or make possible the innovations in the health care system that will assure the system's ability to respond to the demands that are likely to be placed on it in the future.

A principal goal of the NCHSR program is to improve the delivery of health care both in inpatient and outpatient settings through the application of computer technology and information science. The objectives of the program are to develop an Inpatient Care Support System and an Outpatient Care Support System. These support systems are not to be thought of as unitary hardware/software systems that exist in one place at one time. Rather, each is a conceptual framework for a related network of programs, projects, and ideas that may eventually converge into one of the projected support systems. The basic functions of both such systems are to record the component transactions of the care process; to communicate and distribute orders for material, services, and information; to provide information support for both clinical and facility management decisions; to assure that all specified services have been performed; to automate tasks that are either too repetitive or too intricate to be efficiently carried out manually; and to generate and update various reports and files.

The research has been directed toward serving the needs of the health care administrator whose responsibility is facility management and the provider of care whose responsibility is clinical management. In the area of facility management demonstration and evaluation efforts have focused on computer applications that support admitting activities, business and financial functions, medical recordkeeping, cost and resource allocation, dynamic staffing and scheduling, utilization review, medical audit, quality assurance, and patterns of practice. In the area of provider support the focus has been on the provision of diagnostic and prognostic aids, information to improve the selection and individualization of therapy, interactive treatment protocols for physicians assistants and nurse practitioners, record systems that facilitate the continuity of care and the assurance of its quality, and computer consultations for a wide range of special problems.

An overview of the NCHSR technology program from 1968 to 1978 is depicted in Figure 1. The conceptual starting points when the program was initiated in 1968 are shown on the left. The starting point for the Hospital Information System effort was a study that defined the information needs at a hospital nursing station and the knowledge gained from prior unsuccessful attempts to implement large systems. The need for a common, easily programmable computer language became evident when attempts were made to write complex programs that required repeated iterations and a high level of interaction with a medical user. It also was evident that computers could aid physicians in their practice settings, allow them to share clinical experience in databanks, facilitate their access to medical knowledge with consultation programs, and relieve them of certain repetitive tasks through automation. Problems of uneven distribution of medical manpower led to an examination of the role that telecommunications might play in redressing this imbalance. The research projects that evolve from these conceptual starting points are indicated in the center of the figure. The ultimate objective of these activities is shown on the right.

Overview of the NCHSR Program in Health Care Technology—1968 to 1978



The accomplishments of the program are presented in the indented paragraphs below. These paragraphs are variously quotes, excerpts, or summaries from the final reports of the individual projects. The intent is to provide the salient findings of the research in the words that the investigator used to portray them. At the outset, it should be noted that a single project stands out as having been seminal to much of the work in this field. That project led to the development of a special computer language, MUMPS (Massachusetts General Hospital Utility Multi Programming System). Many of the computer programs described throughout this report were written in that language.

> MUMPS was specifically designed and developed to address data management and information processing problems in the delivery of health care. It facilitates the manipulation of text so that any piece of data may be inspected for format or for content (such as particular key words); its hierarchial file structure is tailored for the medical record with its many different levels of importance and detail; and it is a high-level language with its syntax and semantics oriented towards the kind of problems that it will be used to solve, rather than any particular computer (Barnett, HS 00240).
>
> The 1974-1976 interagency agreements between the NCHSR and the National Bureau of Standards to develop a standard MUMPS Language culminated with the 1977 announcement by the American National Standards Institute (ANSI) that the MUMPS Language Standard had joined FORTRAN and COBOL as the only computer languages approved by ANSI (O'Neil, IAA 730001).
>
> During the 1974-1977 project period to demonstrate the value of user groups in the dissemination of medical information, the number of institutions utilizing MUMPS increased over ten-fold, from less than 50 to over 700, and spawned comparable user groups in Europe, Japan, and South America (Zimmerman, HS 01540).

NCHSR has made important contributions in the demonstration and evaluation of information systems as a tool to improve institutional management. The work started with a study of the information needs of a nursing station which was followed by a survey of efforts in the field.

> The patient will benefit from use of Medical Information Systems since the hospital facilities (beds, drugs, and staff) will be more readily available, routine service and emergency responses more timely with reduced errors, and transfer of vital records and third party billings will be handled more expeditiously (Kittle, HSM 110-68-47).
>
> During the period of this study (survey of the state of the art of computer-based automation techniques applicable to hospitals) no single business or clinical system was observed that solved all of the data processing requirements of a community hospital. There is obvious need for some central agency to establish a system of evaluation and standardization to bring a degree of order out of the present chaos. Otherwise, the potential benefits to the national health program through the use of computer-based techniques will not merely be lost, but, unless controlled will be a major contributor to the further spiraling of the cost of health care (Petters, HS 00167).

This early work was followed by an extensive demonstration and independent evaluation of a comprehensive hospital information system (HIS) in a community hospital setting. A study of a modular approach to implementing an HIS also was undertaken.

> A modular approach to implementation of a hospital information system was offered to an associated group of hospitals. They were given the opportunity to test various modules and link them together. Certain modules such as admissions were successfully implemented on a stand-alone basis. Other modules required the synergistic linkage to other modules to make them cost effective. Implementation of all modules on a hospital-wide basis did not prove feasible due to the failure of the administrator to get firm commitments from all of the department chiefs before the project was initiated (Edwards, HSM 110-70-368).
>
> The study results show the HIS has improved the ability of the El Camino Hospital staff to deliver

> patient care as measured by more readily available, more complete, and more accurate information used for providing care and for monitoring patient progress. The timeliness of the administration of tests and procedures improved with the better communication and coordination among nurses, doctors, and supporting departments using the system (Barrett, HSM 110-73-331).

A survey of automated medical record systems in ambulatory care settings was completed and was followed by a demonstration of a Computer Stored Ambulatory Record (COSTAR) system at the Harvard Community Health Plan (HCHP). This demonstration pointed out 4 the utility of the system both in concurrent review and retrospective analysis of practice problems.

> An intensive 1974 effort to identify ambulatory health care facilities that were in some stage of development or use of an Automated Ambulatory Medical Record System (AAMRS) located over 175 sites. Of the 175 sites, only 30 sites met the criteria that the content of the medical record should be high. Of this latter group, only one site showed actual cost savings that exceeded the cost of the AAMRS (Henley, HRA 106-74-118).

There are two HCHP COSTAR concurrent review programs in routine operation. The first identifies patients with a positive throat culture for Beta Hemolytic Streptococci for whom the record fails to indicate appropriate antibiotic therapy. If there is no record of therapy four days after a positive culture, the provider is notified automatically. During the 12-month period prior to using the program, about eight percent of the records which had a positive culture did not contain a record of antibiotic treatment. In the last seven months there were only three cases in which there was no record of appropriate therapy by the tenth day after the positive culture (Barnett, HS 00240).

A similar program follows patients with newly discovered hypertension. Provider-generated criteria specify that within three months of an initial measurement of a diastolic blood pressure equal to or greater than 100, a patient must be re-evaluated. If the pressure is still elevated, the patient must be evaluated again within three months. If still elevated, an appropriate set of tests must be obtained to identify the cause of the hypertension and extent of the disease process. The program is executed every two months to monitor conformity to the standards for patients who had an initial elevated diastolic blood pressure identified six months prior to that time. In cases which fail to meet the standard, the provider is notified by a letter from the Quality Assurance Committee and asked to complete a questionnaire as to whether the standard is in error or does not apply in this particular patient situation, or expaining the cause of the deviation and what is being done to correct the error (Barnett, HS 00240).

Using COSTAR, total population medical record searches were quickly made by the Harvard Community Health Plan for the following (Barnett, HS 00240):

1. A physician needing printouts of the medical records for all patients with a particular diagnosis who were concurrently on a particular medicine.
2. A listing of all women receiving a certain sequential birth control pill, which FDA had removed from the market, so that each could be contacted regarding alternate medications.
3. A nutritionist requesting a listing of all her patients with recorded weight losses of over 10 pounds.
4. A listing of children with incomplete immunization records.

Some effort has been made by the NCHSR to explore the extent to which computers might function to relieve some of the burden in the labor-intensive settings of the Coronary Care and Intensive Care Units. Research results suggested there did not appear to be significant improvements in many instances. Therefore, guidelines were prepared to assist decision makers in the selection and expected benefit from this kind of installation.

> The controlled study in the critical care unit showed no significant difference in morbidity and mortality between the experimental group receiving computer-aided therapy and the control group assisted using conventional techniques, although the data show that the smoothness of blood pressure regulation and the pattern and amount of blood infused was improved in the experimental group (Morgan, HS 01472).
>
> The "Guidelines for Computer-Based Patient Monitoring Systems" permit the hopsital administrator, physician, nurse, and board member to weigh the need against costs in money, time, space, and staff, permitting them to determine if a system is needed and, if so, which one (Wechsler, HSM 110-70-406).

One of the earliest attempts by the NCHSR to help the provider of health care cope with the increasing demands for services was the development of an automated system to acquire, interpret, and report electrocardiograms (ECG's).

> In August of 1972, when the 3-year NCHSR contract to demonstrate a community-wide computer-assisted ECG system ended, the over 20 participating Denver area hospitals elected to continue the project on a fee-for-service basis. In 85 percent of the cases, Denver-area electrocardiographers agreed with the computer printout and made either no amendment or only minor amendments before certifying its validity (Elliott, HSM 110-69-414).
>
> By 1977 over 2,000 hospitals and an equal number of clinics and physicians' offices had adopted the (computer-assisted EKG) technology, primarily through telephonic linkages with national and regional ECG service companies (Drazen, HRA 230 75-212).

A similar effort to automate the flow of information in the radiology department resulted in two interesting and useful systems.

The Missouri Automated Radiology System (MARS) provided the initial demonstration that all the functions of film library management, department recordkeeping, radiology management, and patient scheduling and billing could be computer generated in an information management system acceptable to both the patient and the provider (Lodwick, HS 00646).

The CLIP (Coded Language Information Processing) system of computerized X-ray reporting was developed to permit rapid retrieval of medical information from the vast accumulation of radiologic report files. Such files are now stored using a classification code, representing about a 90 degree reduction in storage space, or the equivalent of storing on a single disk the annual output of a 500-bed hospital doing 60,000 X-ray examinations per year (Simon, HS 01054, HS 02099).

Other projects aimed at improving the operation of the clinical laboratory included efforts to automate the white blood cell count, provide discrete sample handling, and speed the reporting of results.

Nationwide over 100 million differential white blood cell counts are performed annually at a cost in excess of 250 million dollars. The Tufts-New England Medical Center prototype automated cell counter will handle up to 80 percent of the routine test cells and flag the remainder for manual identification by the cytologist, offering potential cost savings of up to 50 percent per automated cell classification, improved quality control, and reduced manpower requirements (Neurath, HS 00696).

The 1974 Connecticut Hospital Association report on hospital costs per laboratory work unit showed the clinical laboratory at the Yale-New Haven Hospital, despite its national rcognition for high quality control, the lowest in the state at $.08 per unit compared to $.10 to $.12 per unit for other hospitals in the state (Seligson, HS 00075).

The Youngstown Hospital Clinical Laboratory System, developed over a six-year period with NCHSR research monies, now provides routine clinical service to a consortium of three area hospitals. It is accessible via an inexpensive ($50) adapter to a standard touch-tone telephone by all referring physicians who receive the lab results by computer-generated "voice answer-back." Another feature, "Auto Call," phones the physician at the instant the lab results are available and by computer-generated "voice answer-back," urges that the results be used as quickly as possible in the hope of shortening the patient's stay (Rappaport, HS 00060).

Some effort was made to introduce automation into the private practice setting. Two projects, CAPO and On-Line Medicaid Claims Billing, addressed various physician office activities.

The assessment of the utility of Computer Aids in the Physician's Office (CAPO), shows that the most cost-effective way of providing computer services to medical office practices will be through small stand-alone systems rather than through in-office terminals supported by a remote service bureau (Castleman, HSM 110-71-244).

Medicaid billings were entered on-line from the physician's office using a standard Touch Tone telephone equipped with an inexpensive Card-Dialer. The data were immediately checked by computer-generated "voice answer-back" for patient eligibility, appropriateness of the charge, and confirma- 5
tion of the diagnosis and therapeutic procedures. The total daily transactions for the almost 200 participating physicians could be transmitted to the carriers, appropriate state agencies, and eventually the banks in machine-readable form, resulting in improved cash flow for the physician and reduced costs of data preparation and audit by all parties Mesel, HSM 110-71-252).

Another major area of activity of the NCHSR has been to explore ways to facilitate the physicians' access to the body of medical knowledge that is usually reserved for specialists. This type of activity is exemplified by a number of projects that in effect attempt to provide expert consultations to the generalist. A program designed to help physicians manage patients with electrolyte imbalance was successfully developed and tested. This was followed by development of an improved system for assisting in caring for patients with urinary tract infections, by MYCIN that assists in antibiotic selections, by Monitoring and Evaluation of Drug Interactions, by a Pharmacy-Oriented Reporting System (MEDIPHOR) that warns of potential drug interactions, by CARE that guides the provider in the management of certain critically ill patients, and by HELP, (computer program to help physicians) that addresses a much wider range of practice problems.

For each one million population, 200,000 sets of electrolyte determinations per year are performed at a cost of $2.5 million, e.g., in Boston $7.5 million are transferred from patients and third parties to laboratories and hospitals as payment for these determinations. In the non-university-affiliated hospitals, approximately one-fourth of the measured electrolyte values were markedly abnormal. When the charts of these patients were examined, half showed evidence of significant mismanagement according to the conservative criteria used (Bleich, HS 00188).

Testing the (Electrolyte and acid-base evaluation) computer program using board examination nephrology questions in the American College of Physicians' Self-Assessment Examination, a previously untrained individual was able to outperform 98 percent of physicians who consider kidney and electrolyte disorders to be their area of special interest (Bleich, HS 00188).

Urinary tract infections in women are a common, important medical problem for which professional help is sometimes unavailable and always expensive; these infections are erratically treated and poorly understood. An interactive computer can provide the basis for helping the patient from the time she presents with dysuria, through the generation of a prescription for therapy, to a series of follow-up sessions that check the safety and effectiveness of the treatment (Bleich, HS 00188).

The MYCIN (artificial intelligence) program is
6 of interest to computer scientists because of its novel organization of clinical, pharmacological, and microbiological knowledge, its methods for acquisition of new inference rules, its use of the knowledge to give advice, and its ability to explain the reasons for its decisions (Cohen, HS 01544).

Although no effect on length of stay could be seen, the MEDIPHOR evaluation study did detect some important and statistically significant changes that can be attributed to the system: the number of prescriptions per patient was reduced by 10 percent, the rate of interacting prescriptions by 14 percent, and the percentage of patients receiving more than one interacting pair of prescriptions dropped from 3 percent to 2 percent (Cohen, HS 00739).

Using measured and derived parameters about the individual patient and the disease state, the CARE system developed at the Buffalo General Hospital supports the attending physician by recommending the appropriate therapy for the critically ill patient suffering from burns, trauma, or cardiovascular-respiratory shock (Siegel, HS 01195).

The ability of the HELP system implemented at the Latter-Day Saints (LDS) Hospital in Salt Lake City to generate data for analysis of medical practice may prove to be its most valuable feature. Because the system automatically reacts to each new data entry and examines it in the context of previous data on this patient according to rules specified by the medical logic stored in the form of decision criteria, the appropriate medical knowledge can be promptly brought to bear on each patient's problem (Warner, HS 01053).

A comprehensive attempt to guide the physician in caring for his patient is embodied in the Problem Oriented Medical Information (PROMIS) System. This system contains an extensive body of medical knowledge that the provider can access in the course of ordering and recording care transactions. Another system using protocol-based remainders prompts the provider to carry out a previously established protocol.

PROMIS was designed to solve four important problems existing in the practice of medicine: lack of coordination among those who supply care to patients; excessive reliance on memory in the delivery of care; lack of recorded reasons why observations were made or specific actions taken; and lack of feedback loops, which prevents the use of patient information to improve the care of an individual patient. Through its requirements for explicitness and its coupling capability, PROMIS not only points out those areas which require coordination between health care personnel, it also reveals where such teamwork is lacking. It collates and records all data according to the relevant medical problems so that each medical services provider is aware of the reason for the service and how it relates to the total medical care (Weed, HS 00175, HRA 239-760099).

The results of this study are most consistent with the initial hypothesis: that the amount of data presented to the physician per unit time is more than he can process without error; the computer augments the physician's capabilities and thereby reduces his error rate (McDonald, HRA 106-74-18, HS 02485).

An effort by the NCHSR to explore the feasibility of using a shared clinical experience to manage patients with chronic illness resulted in the establishment of two databanks, one with extensive clinical data on patients with coronary artery disease, and the other on patients with rheumatic diseases. Both of these efforts have important implications for improving clinical management and reducing the costs of care.

What is needed is a methodology which deals with the complexity of chronic illness, one which ties the output of clinical research to the care of individual patients and one which provides the best way to validate clinical observations with more clinical observations. Carefully collected data in the continuously growing information base at Duke University showed that the addition of more patients to the subgroup previously reported as having a higher survival if treated surgically (aortocoronary bypass) failed to confirm that observation (Rosati, HRA 230-76-0300).

Although various studies previously found that many heart attack patients can be discharged safely earlier than has been the practice, the Duke University study is the first to suggest that discharge can safely be made as early as seven days after the heart attack. Early discharge of the heart attack patient could save the patient or his health insurance plan $1,500 to $2,000 and, if practiced widely, could save $360 million off the Nation's annual medical bill (Rosati, HRA-230-76-0300).

The American Rheumatism Association Medical Information System (ARAMIS) maintains a group of nine parallel databanks accessible through a national communication network and contains data on over 6,000 patients, 30,000 patient visits, and 10 million data items covering 19,000 patient years of observation by 37 institutions. The databanks were developed for particular institutional strengths. Examples of these orientations are databanks for connective tissue disease, epidemiology, juvenile arthritis, myositis, systemic lupus erythematosis, community practice of rheumatology, adult arthritis, reconstructive surgery, scleroderma, SLE, myositis, and Raynaud's phenomenon (Fries, HS 01875).

A cluster of exploratory projects examining the utility of a variety of telecommunications techniques in rural and urban health-care settings has been undertaken by the NCHSR. The experience gathered from these activities was incorporated into a handbook.

NCHSR-supported research in the use of telecommunications technology demonstrated that telemedicine improves communication between health care facilities and facilitates the transfer of patients between facilities having varying levels of medical expertise. It also can be equally effective in avoiding unnecessary patient transfers (O'Neill, HRA 106-74-182).

The bi-directional cable TV system linked the group practice, its satellite clinic, and the 110-bed Waconia (Minn.) hospital. The physician in the geographically isolated clinic was able to "visit" with his hospitalized patients and "attend" emergencies, without closing the clinic and depriving the rural area with needed primary care services (Wempner, HSM 110-72-386).

The Nebraska project used slow-scan television, similar to that used to send pictures from the moon, to transmit X-ray images from rural hospitals to the Nebraska Medical Center. The availability of expert radiologic advice resulted in the immediate transfer of some patients who suffered from conditions more serious than suggested by the admitting diagnosis to the University Hospital with its specialized facilities (Wilson, HS 01210).

In the East Harlem cable television project, almost 80 percent of the neighborhood clinic's television consultations were sufficiently complete to avoid having to send the children to the orthopedic clinic at the Mt. Sinai School of Medicine (Marshall, HSM 110-72-382, HS 01392).

In Cleveland's Case Western Reserve University Hospital, expert pediatric consultations were made available, using two-way television, to a small inner-city hospital. The expert was able to "visit," on a daily basis, each infant in the newborn nursery and in the pediatric intensive care unit and discuss its progress or problems with the nursing staff. A second link enabled the University-based anesthesiologist to provide back-up support to the nurse anesthetist at another remote hospital (Gravenstein, HSM 110-72-383, HS 01390).

The analytical tools that can narrow the range of R&D projects and field trials needed are discussed in "The Telehealth Handbook: A Guide to Telecommunications Technology for Rural Health Care." The Handbook provides information to potential users of the technology interested in initiating a telehealth project, and discusses a range of technologies from expensive interactive video and computer-supported systems to the inexpensive narrowband systems using standard telephone equipment (O'Neill, HRA 106-74-182).

Inpatient care support system

The cost of hospital care is increasing at a faster rate than any other sector of the national economy. This increase was 100 percent in the short span from 1970 to 1975 even though wage and price controls were in operation for the hospital industry for approximately half of this period. Since 1950 the cost of a hospital bed day has risen more than 1,000 percent (Feldstein and Taylor, 1977), placing in jeopardy the national goal of providing health care to all citizens and seriously burdening current programs such as Medicaid and Medicare. The quality of inpatient care is also an important concern. Rising malpractice insurance rates are causing providers to seek new ways of assuring acceptable quality of care. Policymakers, seeing growing evidence that current trends are causing over-utilization of some resources and under-utilization of others, are seeking improved methods for performing medical audit and utilization review.

The NCHSR Technology Program has supported, directed, and coordinated research directed at applying computer technology to improve the quality of inpatient care while reducing or containing its cost, with special emphasis on applications concerned with information processing. The areas of a hospital most affected include the nursing areas (where care is delivered), ancillary support departments (e.g., clinical laboratory), management (including business office), emergency care, and specialized applications such as automated patient monitoring in intensive care units. All of these applications involve information processing.

The main thrust of the Inpatient Program is to evaluate and demonstrate new applications for existing technology. Only relatively minor system development efforts are currently being supported. As interest in these systems grows in the hospital community, NCHSR feels the responsibility to provide the user community with research data to enable them to develop effective guidelines and recommendations concerning the acquisition, implementation, and operation of this technology.

The principal components of the inpatient effort are hospital information systems, clinical laboratory systems, radiology systems, computer-assisted electrocardiography, patient monitoring, and emergency care.

Hospital information systems. It has been suggested that the primary reason for the rapid rise in the price of hospital care is the willingness of patients to pay for expensive care (and doctors to order it) because insurance now finances a much larger share of those payments (Feldstein and Taylor, 1977). Whether high prices are due to inappropriate use of medical resources, which is encouraged by present insurance practices, or are caused by legitimate increases in the costs of services is difficult to determine and harder still to control. To meet this challenge of spiraling prices, research efforts must be directed towards helping the hospital industry become more efficient, while maintaining or improving the quality of the care it delivers. A promising tool for achieving these ends appears to be the Hospital Information System (HIS) (Hodge, 1977).

It is estimated that information processing accounts for as much as 23 to 39 percent of the cost to care for inpatients (Jydstrup and Gross, 1966; Richart, 1976). If this cost can be reduced and at the same time the scheduling of personnel and services can be made more efficient, considerable savings in the overall costs of hospital care would be achieved. Hospital Information Systems also support activities such as utilization review and PSRO programs which are aimed at reducing inappropriate and unnecessary services (Jacobs, 1976; Schmitz, 1976), and provide improved patient care processes (speedier reporting of laboratory results and reduced medication errors) and more easily retrievable medical information (surgical abstracts of pertinent new procedures). The NCHSR used the results of early projects which helped define the problems (Garrett, PHS 108-66-299; Kittle, HSM 110-68-47) to develop a demonstration and evaluation plan which proceeded along two lines. One approach was the demonstration and evaluation of a comprehensive hospital information system designed to link all nursing stations and service departments and to replace substantial portions of the current manual system of ordering, reporting and recording. The other approach was to demonstrate and evaluate modules (laboratory, pharmacy, etc.) on a serial basis with the intent of eventually linking up all the modules at the nursing stations to form a comprehensive hospital information system.

Although modular implementation initially seemed to be a more desirable approach in terms of cost and ease of implementation, the experience with two projects (Gall, HSM 110-71-128; Edwards, HSM 110-70-368) suggests that the comprehensive system implementation may be the better approach. In 1971, NCHSR awarded a contract to El Camino Hospital, Mountain View, California to implement and demonstrate a comprehensive HIS (Gall, HSM 110-71-128). A second contract was awarded to Battelle Columbus Laboratories to perform an independent evaluation of the impact of the system on the hospital (Barrett, HSM 110-73-331). Based on results of these projects, a number of conclusions can be drawn:

1. HIS systems can be exported to different types of hospitals (Hodge, M.I.S., 1977).

2. Nurses and physicians will use a well-designed system (Barrett, HSM 110-73-331, 1975).

3. The hospital community is poorly informed about this technology (DuBois, C.A.F.I.A.M.I.S., 1976).

4. A benefits realization program is necessary to reap the cost benefits of HIS (Gall, et al., 1975).

5. HIS provides a variety of benefits to the hospital, medical staff, and the patients, including increasing productivity and providing more readily available, more complete, and more accurate information for inpatient care (Barrett, 1975).

The Battelle report measuring the economic impact of the HIS at El Camino Hospital will be available by August, 1979.

Interest in and availability of commercial HIS's has grown steadily and over ten vendors offer systems ranging in complexity (and cost) from simple order entry, charge capturing, one-way systems to comprehensive HIS (Technicon MIS) capable of storing and making retrievable major portions of the medical record and providing functional applications such as charting of medications, patient profiles, and nurse care planning. NCHSR has also supported the development of the Problem Oriented Medical Information System (PROMIS) at the University of Vermont (Weed, HS 00175; HRA 230-76-0099), a system which will have the message switching capabilities of the most advanced HIS plus several innovative features including total medical record storage, a sophisticated medical care guidance system, and an exceptional data base from which to perform utilization review and medical audit.

Hospital Information System implementations will sharply increase during the next few years. If the largest 2,000 hospitals in the United States were to acquire comprehensive HIS's it is estimated that a market in excess of $2 billion would have been created. Current commercial investments in the development of HIS appear adequate; however, Government support for the development of new approaches to medical care (e.g., PROMIS) is needed and the NCHSR hopes to continue to support such activities.

The amount of objective information on HIS technology and the benefits that can be derived is almost nonexistent and, with the exception of the El Camino Hospital project, there have been no objective studies undertaken to evaluate HIS in operational settings. Activities aimed at educating the user community (hospitals) have been too general and not particularly objective (much of the information has been provided by the vendors); consequently, our future HIS activity will focus on educating the user community and evaluating the technology. A primary emphasis in the education process will be the proposed development of a HIS handbook for use by hospitals, a looseleaf document that can be periodically updated as new information becomes available. Supplemented by periodic HIS workshops and symposia, it should fill the void of needed information. In the evaluation area new studies of the scope, time, and cost of the El Camino Hospital project probably will not be launched. One new evaluation approach under consideration would define potential benefits, including measurable cost savings based on existing and anticipated information processing requirements. Actual benefits could be documented after a reasonable time following system implementation. Another approach would employ targeted case studies of HIS implementations, emphasizing the benefits realization process and the implementation experience.

Clinical laboratory systems. The NCHSR contributions in the area of clinical laboratories have been in the development of an automated white blood cell analyzer, a discrete sample analyzer, a computerized voice answer-back device for automatically reporting laboratory results, and in the evaluation of some of these systems. In the United States about 5 billion clinical laboratory tests are made per year in the over 7,000 independent clinical laboratories, 7,000 hospital laboratories, and the estimated 88,000 physician office laboratories.

In the last 10-15 years, demands placed upon health care facilities to provide accurate and rapid processing of patient test specimens have exceeded the capacity of manual methods. In the current state of the art, large computer systems that automate the assay process are interfaced directly with information systems that process massive quantities of data and reports, and keep accurate records of medical, statistical, and financial information. These systems effect systematic organization of laboratory results into a readily accessible data bank for use in patient care and research, eliminate clerical errors, make results available more rapidly, and increase staff productivity. NCHSR supported the development of the Tufts-New England Medical Center prototype, automated, interactive computer system for differential white blood cell counting (Neurath, HS 00696). At Yale University, a discrete sample analysis system has been developed that reduces the number of tests performed, improves quality control, enhances communication of laboratory results to the referring physician, and reduces laboratory costs (Seligson, HS 00075).

At the Massachusetts General Hospital, a modular, computer-based laboratory information system has been developed that is one of the largest in the United States (Barnett, HS 00240). The laboratory computer system, programmed in MUMPS language, includes the following: (1) a file-oriented information processing subsystem for receiving specimens, preparing worksheets and laboratory test reports, answering test result inquiries, and providing accounting and statistical reports for management; (2) on-line support for a variety of terminal displays that permit multiple users to perform multiple functions simultaneously; and (3) an interactive capability with rapid response time that facilities quality control through the immediate detection and feedback of errors.

10 At the Youngstown Hospital, a computer-based clinical laboratory system has been developed for three hospitals that share clinical laboratory services (Rappaport, HS 00060). Over 25 chemical and hematological testing instruments are interfaced with the computer system. Inexpensive Touch Tone key pads allow physician users to order tests and obtain the results by computer-generated voice answer-back as soon as they are available. A further refinement, "Auto Call," automatically telephones the results of tests to the doctor at the ward or at his private office outside the hospital as an encouragement for him to begin treatment or discharge the patient sooner and reduce the hospital stay. A current study is investigating this interval between the time the physician receives such information and the time he makes patient management decisions.

Radiology. Radiology is one of the most costly of health services, with over 240 million X-rays recorded annually. One of the more prominent problems in radiology is concerned with the reporting and recording of the radiologist's X-ray interpretations. In conventional systems, according to the American College of Radiology, over 95 percent of all interpretations are dictated. The radiologist dictates his findings into a dictaphone and a typist transcribes the report for his later review and signature. Experience in various hospitals indicates that it takes one to five days to produce this report and get the information to the referring physician. Automated computerized radiology reporting systems that reduce the time to produce standardized text reports are commercially available. However, although these systems reduce the time to distribute the X-ray report, they place additional burdens on the radiologist.

The University of Missouri Automated Radiology System (MARS) was developed for computerized management of dictated reports, scheduling, and film tracking. It recently has been extended to provide on-line X-ray interpretation reporting by use of computer terminals displaying a set of possible alternatives-related statements. The radiologist types in a number corresponding to one of these statements and is given the option to elaborate on these statements by requesting a further list of choices. Thus, the radiologist constructs his report directly on the CRT terminal, and the report is instantly available at all the wards. Currently, 70 percent of the radiologists use this system instead of the traditional dictaphone. MARS is also used for management of the activities of the radiology department. The system schedules patients (resulting in less waiting time) and keeps track of X-ray film. This is accomplished by having clerks type the appropriate information into a CRT terminal. Schedules and films are marked by bar codes (similar to those used in supermarket check-out stands) and a light pen is swept across the bar code instantly reading and recording the data (Lodwick, HS 00646).

An American College of Radiology project at the University of Arkansas, developed a Diagnostic Radiology Information System (DRIS) which allows the radiologist to dictate his report in the usual way, but includes a computerized retrieval system that assists the radiologist in his current interpretations by retrieving old reports and displaying them on the CRT. The system catalogues reports using a standard radiology thesaurus, operating similarly to an on-line standard library-type retrieval system. Although used at the University of Arkansas, it did not find acceptance at other hospitals (Barnhard, HS 00525).

At the University of Vermont, a radiology reporting system has been integrated with the computerized Problem Oriented Medical Record System (PROMIS). The radiologist interfaces directly with the terminal, entering his report by selecting with his finger the appropriate phrase or descriptor displayed on the "touch-sensitive" CRT screen. Many thousands of CRT display frames have been developed for this purpose. The system has not been tested outside of the University of Vermont (Weed, HS 00175).

The Framingham Union Hospital Rapid Telephone Access System consists of a bank of tape cassettes into which the radiologist dictates his report. The referring physician then can access the report by telephoning the cassettes. The system has not been acceptable to radiologists because of the waiting time to access cassettes by telephone and because the system does not allow the compilation of statistical and other time-related reports (Weintraub, HS 01508).

At the Massachusetts General Hospital, a radiology subsystem has been integrated with the computerized medical record system. A 1974 study, using 7,000 X-rays, required the radiologist to select choices on the CRT terminal with a light pen. The frames were arranged using a hierarchial, branching tree logic with important interconnections between portions of the tree to avoid the display of unnecessary material. Each choice led to another display frame which permitted the entry of modifying terms. The radiologists tried the system for nearly a year, but never accepted it because of the reluctance to use the computer terminals. It is important to note that this system was not integrated into the COSTAR medical information system developed for the Harvard Community Health Plan terminal (Barnett, HS 00240).

A Temple University evaluation of the Radiology Reporting System (RAPOR) showed that even though such systems are cost effective, they will not be widely accepted by radiologists because of the time needed to fill in mark-sense cards. A computerized interactive scheduling system, Temple X-ray Scheduling (TEMPLEX) also was evaluated, and although there is still competition between inpatient and outpatient desks as to whom should be put in what room, the system has been accepted by the hospital because it reduced patient waiting time and increased throughput (Shea, HS 01566).

At the Beth Israel Hospital in Boston, a shorthand Coded Language Information Processing (CLIP) system has been developed that allows the radiologist to type 1 or 2-digit codes directly into a CRT terminal. Each code produces a standard paragraph of the X-ray report on the screen, so that only the bare minimum time of the radiologist is required. The menu of codes and other choices presented on the CRT terminal forces the radiologist to input terse, structured information and makes the information more reliable and retrievable. The system currently is under evaluation. In a second project, a voice-actuated system in which the radiologist's voice is encoded and serves as a direct input to the computer is being developed. Since dictation is the preferred method of reporting by nearly all radiologists, the voice-actuated system may be more acceptable to them and still permit the report to be instantly available to all parts of the hospital (Simon, HS 02099).

Computer-assisted electrocardiography. The 12-lead resting electrocardiogram (ECG) is the most widely used of all medical procedures in the prevention, diagnosis, and treatment of heart disease, and current estimates of its use approximate 80 million tests performed each year at an annual cost approaching two billion dollars (Dreifus, 1978). The use of computers to analyze the ECG was first demonstrated prior to 1960 (Caceres and Barnes, 1969; Pipberger, 1965), although it was not until 1969 that Computer-assisted Electrocardiography (CAE) became an acceptable diagnostic procedure routinely used in health care delivery settings. Barriers to its earlier adoption included computer costs, an inadequate (high noise) telephone system, and the bulk and complexity of special acquisition equipment required to record an ECG for computer analysis. Private sector R&D investments in digital recording and transmission techniques, (not specifically addressing health care delivery needs) were largely responsible for overcoming these barriers. Since 1969 the private sector has continued to absorb the major costs associated with system "packaging," human engineering, and software development, while federally supported efforts have emphasized demonstrating the technology (Elliott, HSM 110-69-414), cost effectiveness studies (Drazen, HRA 230-75-212), and technology transfer (Hsieh, IAA 0003). Between 1969 and 1973 NCHSR distributed over 400 copies of its ECG Analysis (ECAN) program to health care institutions. Widespread adoption of the technology really did not begin until 1972; however, the rate of growth has been about thirty to fifty percent per year over the last few years. It is doubtful that commercialization and diffusion would have occurred as rapidly without early Federal support.

The major benefits associated with the computerization of electrocardiography are usually reported as reduced turn-around time, increased accuracy, improved quality of tracings, and increased access to ECG services, although one epidemiologic study reported an improved diagnostic capability and a 1976 survey reported some cost containment.

> In a follow-up study, the 5-year incidence of myocardial infarction was significantly higher among those subjects whose electrocardiograms were computer-interpreted as giving evidence of possible or probable infarct, but in whose paper tracings the cardiologists found no signs of infarct, (Newfield, 1973).
>
> The cardiologist is reported as requiring approximately 60 percent less time to interpret an ECG when assisted by automation, a reduction expected to be translated eventually into a decrease in cost and reimbursement charges. This probably will take the form of cost containment; that is, cardiologists' fees will not rise as rapidly as inflation. This effect has already been observed at one site, and cardiologist fees are now approximately one-half of what they would have been otherwise. Another site had lowered cardiologist fees following automation (Drazen, HRA 230-75-212).

When the above data are combined with data from other manpower utilization studies, they show that the use of Computer Aided Electrocardiography (CAE) reduces the average reading time of the cardiologist from 125 seconds per ECG to 31 seconds. A savings of approximately 1,000 cardiologists man years would be realized if all eighty million ECG's were so interpreted. The impact of shifting this time saved to direct patient services has not been evaluated, nor has the implication for future medical curricula been examined. There currently are almost 100 operational computer systems in the United States providing CAE services to over 2,000 hospitals and an equal number of physician offices and clinics. By the year 1980, it has been estimated that over 100 million electrocardiograms will be taken annually and 1,500 analysis centers will be in operation in the U.S. (Frost & Sullivan, 1974).

One of the recommendations specified at the American College of Cardiology Conference "Optimal Electrocardiography" (April, 1977) was that every adult American should have an electrocardiogram for the purpose of providing base-line information concerning their cardiac status (Dreifus, 1978). Federal incentives are not needed or desirable to enhance further diffusion of this technology, and certificates-of-need requirements are not likely to have a negative impact on the expected diffusion of CAE. The targeted market for the next five years will be the smaller hospitals and physician offices that are more likely to contract for the service on a "per ECG analyzed" basis rather than purchase an analysis system. However, the rapid diffusion of computer-assisted electrocardiography has emphasized the need for national standardization of diagnostic criteria and interpretative statements, and the establishment of a data base for further ECG research. There is a need for a service that would compare existing or contemplated CAE computer programs.

Automated patient monitoring systems. In the late 1960's and early 1970's, NCHSR supported the demonstration and evaluation of computer-based automated patient monitoring systems designed to aid nurses and physicians in the care of critically ill patients by providing continuous or intermittent monitoring of physiological parameters. The specific monitoring capabilities of these systems are determined somewhat by the type of patients being cared for; however, all of the systems monitor the basic variables such as blood pressure, heart rate, and temperature. Certain specialized systems are available that monitor respiratory parameters and cardiac arrhythmias. It was assumed that these systems would increase nursing productivity and improve the quality of care. Productivity would be increased by reducing the need to repeatedly observe and record manually physiological data, quality of care would be enhanced by the continuous monitoring of physiological data allowing one nurse to care for more patients; quality of care would be enhanced by the continuous monitoring of the physiological data, allowing the physician (or nurse) to more accurately assess the status of the patient and be forewarned of impending crises. Vendors marketing automated patient monitoring systems offer designs ranging from relatively simple systems that measure the parameters listed above, to rather sophisticated systems that can automatically infuse blood, fluids, and drugs, and are controlled by physiological demand. In 1975 there were approximately 30 systems in operation nationally. Currently, there may be twice that number and the market potential is estimated to be two thousand units at a total cost of $200 million (Wechsler, HSM 110-70-406, 1975).

Automated patient monitoring activities initially involved system demonstrations in several hospitals. An evaluation contract, awarded to an independent organization for the purpose of evaluating the impact of this technology at these sites, later was expanded to include other systems which were not supported by NCHSR. The evaluation showed that system costs vary considerably depending on the configuration, but generally range between $15,000 and $25,000 per bed, in addition to the typical bed/day operational costs of $55 to $110. The number of nursing staff required to care for patients was not reduced, although one system allowed the substitution of lesser trained staff (LPN's) for more highly trained personnel (RN's) (Wechsler, DHEW Publication No. 76-3143, 1977).

Although users have reported that the patient's life was "saved" by such systems, there is no definitive, quantitative evidence to indicate the systems have changed overall patient mortality or morbidity. The systems have affected physician and nurse behavior, and when used in a feedback mode tend to standardize patient care and prevent the dips often encountered during night shifts. Further, the nurse spends more time tending to the patient and less time collecting and recording data. An evaluation at the hospital of the University of Pennsylvania reported that its system did not show a realistic cost/benefit ratio for computer-aided monitoring of postoperative cardiac patients; it did not influence morbidity or mortality; and it did not significantly alter nursing activities (Edmunds, et al., 1977). Although some benefits are derived from the use of these systems, it is not clear that this approach is a judicious use of resources for most hospitals. Guidelines for the acquisition, implementation, and operation of automated patient monitoring systems were developed by NCHSR. Stressing the marginal utility of this technology, the guidelines also offer hospitals, determined to acquire such systems, additional information on the best way to go about it (Wechsler, DHEW Publication No. 76-3143, 1977).

Emergency medical care. Section 1205 of the Emergency Medical Services (EMS) Systems Act of 1973 (Public Law 93-154) and of the EMS Amendments of 1976 (Public Law 94-573) authorize a program of research in "emergency techniques, methods, devices, and delivery." NCHSR is the DHEW organization responsible for administering this applied research effort and has funded several projects which use computer-supported systems and modules for providing appropriate care in life-threatening medical emergencies. These activities emphasize evaluative research, including analyses of the performance of systems and their components. Project results will be applied to current and future operational EMS systems to make them more efficient, effective, and responsive to the needs of the communities they serve.

Emergency medical services can be divided into three components: the immediate care outside of inpatient facilities (mobile rescue units manned by paramedics), the emergency facility (hospital emergency room), and the inpatient care (intensive care unit and shock treatment unit). The use of computers has largely been limited to the intensive care areas and to a lesser extent the emergency room. Optimal management of medical emergencies occurring in the hospital includes methods for early detection so that appropriate action (triage, diagnosis, and treatment) can take place in a timely manner. At the Latter Day Saints Hospital in Salt Lake City, Utah, a computer-based system has been developed for hospital-wide monitoring which, according to fixed protocols, gathers physiological and clinical data on patients. It then uses these data to recognize patterns indicating a threat to life and alerts the medical staff of patients who may need more intensive care and monitoring before catastrophic conditions develop that necessitate heroic life-saving procedures (Gardner, HS 02463). The system also provides therapeutic assistance (using stored protocols) in the treatment and management of patients in intensive care facilities.

Another project stresses support of medical staff in the critical care areas. The Clinical Assessment Research and Education (CARE) system at the University of Buffalo is a consultative aid not only for postsurgical patients, who often present the most complicated metabolic problems and difficult recovery courses, but also many acute medical problems of an emergent nature (Siegel, HS 01195). The system relates these important problems to the most recent literature as a "living textbook," and permits the physician to gain information from, and communicate with, other members of the health care team. A nationwide time-shared computer service now allows widespread and easy access to the system.

Computers are being effectively used for activities that indirectly affect EMS systems in a project to develop a computerized methodolgy for evaluating emergency medical care performance (Wolfe, HS 02902). If successful, this approach could become a national resource for use by communities in assessing the effectiveness and efficiency of their EMS system. Another project is developing a computerized quality assurance system that will benefit health care providers and administrators of Emergency Medical Services by providing an objective means for measuring quality of care and for improving care through educational feedback of audit results. The use of computers in EMS systems is expected to increase, along with applications aimed at improving the education and effectiveness of EMS personnel. The new small and inexpensive portable computers should find wide application in mobile emergency vans and as hand-held devices to assist in procedures such as cardiopulmonary resuscitation and shock treatment.

Outpatient care support system

Much of the health care delivered in this country is on an ambulatory basis. There are approximately one billion outpatient encounters each year or about four million persons seen per week day, and the cost of providing outpatient care consumes a major portion of the Nation's health dollars. As a result of rapidly increasing costs of hospitalization third-party payers are enforcing increasingly stricter reimbursement criteria for hospital services, which in turn increases the demand for health care services delivered in already overburdened outpatient facilities. The NCHSR technology effort in Outpatient Care Support Systems provides support, direction, and coordination for the cost-effective utilization of technology that increases the quality and accessibility of outpatient health care. A primary objective is to develop methods for defining the need for technology, and adapting, and utilizing existing technology. A secondary objective is to develop specific technologies where existing technologies cannot be usefully configured or adapted to ambulatory health care delivery requirements.

Certain activities have been initiated that represent concrete steps in an iterative approach to achieve the above goals. One of these activities is to continue the development of technologies to meet high priority needs, such as the shortage of health care manpower and the inefficient handling of information. Another activity is the careful analysis of existing outpatient systems in an effort to precisely identify and define those conditions that limit access, increase costs, and inhibit high quality care, and that are potentially amenable to improvement through technological approaches. A further activity is to develop and implement specific methodologies for evaluating current and future projects in outpatient care to determine whether the introduction of innovations has produced some measurable benefit.

The main thrust in Outpatient Care Support Systems has been directed towards the development of an automated ambulatory medical record system. This appeared to be the critical activity and the one upon which the remainder of the program might be built. Such a system would address the major data and information processing needs in the outpatient setting. It would also provide a sound base from which other ambulatory services might be introduced, such as the automated processing of the electrocardiogram, use of computerized aids for physicians, and use of telecommunications to extend the reach and improve the level of care.

Automated ambulatory medical record system. Automated Ambulatory Medical Record Systems (AAMRS's) have the capability of performing all or most of the registration, scheduling, accounts receivable, and medical record-keeping functions necessary to operate an ambulatory care facility. Since all data are stored in computer-retrievable form, they are immediately available to the health care provider to aid in patient management decisions and to the facility administrator to guide resource allocation decisions. The medical record component may include history and physical examination data, laboratory and radiology test results, and such clinical information as progress notes, problem lists, presenting symptoms, diagnoses, and therapeutic interventions. Some AAMRS's have report generation capabilities that enhance the continuity of patient care and facilitate quality of care assessments and utilization review procedures. A study of technology utilization in rural health care strongly suggests that an AAMRS with all of these functions would assist physicians in medical decision making and patient care activities and would offer significant benefits in terms of the quality of patient care (Fifer, 1975).

Although there are numerous medical billing systems on the market, the number of AAMRS's that encompass all of the above functions is significantly smaller. The

NCHSR-sponsored state-of-the-art report which identified approximately 175 AAMRS installations found only 30 that performed the medical record function, and less than a dozen of these were fully operational (Henley, 1975). As computer hardware costs continue to decline, AAMRS's will become increasingly attractive to group practices, health maintenance organizations (HMO's) and ambulatory care clinics. However, unlike many other technologies AAMRS's do not generate additional revenues (as does an X-ray machine); the capital outlay, transition costs for entering records that had previously been kept on paper and recurring operating costs must be absorbed into the charge for each patient visit or service provided by the ambulatory care facility. Up to the present time, the major incentive for buying an AAMRS has been the automated billing function. Data from another NCHSR AAMRS study indicate that the costs of maintaining an AAMRS can be offset by reduced personnel costs for the billing function alone, with total savings resulting from increased personnel productivity projected at $90,000-$140,000 per year for a medium-size group practice (Pickett, 1975).

AAMRS's improve communications between providers by making the medical record more accessible, timely, legible, and better organized. Quality of care can be audited more easily and groups of patients "at risk" identified. Unfortunately, many of these benefits do not represent sufficient incentives for the physician to overcome the large capital investment required. Other disincentives are concerned with privacy problems and the structured input requirement found objectionable by some practicing professionals.

Computer Stored Ambulatory Record (COSTAR) was developed by the Massachusetts General Hospital to meet the information processing needs of the Harvard Community Health Plan (HCHP), a Boston-based HMO serving over 100,000 patients (Barnett, HS 00240). Interactive computer terminals at each data entry point in the clinic are used by clerks who routinely enter all medical and administrative data. This significantly reduces the amount of paper generated in the process of registration, scheduling, entering medical data and accounts receivable/billing. After the NCHSR demonstration ended in 1977, the system was fully supported by HCHP from operating revenues. This success of COSTAR at HCHP was largely responsible for the intensified efforts by NCHSR to develop a less expensive and more exportable version of COSTAR for application in smaller ambulatory care settings. COSTAR V, the result of an NCHSR Intramural Research activity that involved the resources of the George Washington University (Yamamoto, HS 01449), the Massachusetts General Hospital (Barnett, HS 00240), and the Digital Equipment Corporation meets both of these requirements and fulfills all of the information processing functions mentioned above. A public domain version of the software, written in Standard MUMPS, will be implemented in a group practice setting under two pending NCHSR contracts to demonstrate and evaluate the efficacy and cost effectiveness of the system. A NCHSR strategy for software dissemination, technical assistance to adopting institutions, user group feedback mechanisms, enhancement of technical dcoumentation and user manuals, and procedures for transferring the technology to private industry is under development. Plans to use COSTAR V as the vehicle for introducing other technological innovations into ambulatory health settings are under consideration.

Computer aids in the physician's office. There is a paucity of information in the literature concerning systematic application and evaluation of computer technology in the private practice setting. In the early 1970's a demonstration of such applications, "The Automated Physician's Assistant Project," was implemented by the University of Missouri in a small rural clinic. However, it was found that the technology had not advanced to the point where it was useful in a clinical setting. Specifically, the costs were high, the response times too slow, and the memory capacity of the computer too small. Further, the instrumentation was cumbersome and complicated and inadequacies of the telephone system caused noise and signal interference problems that affected the accuracy and completeness of the transmission (Lucas, HSM 110-72-149).

In 1972 NCHSR began a 3-year project, "Computer Aids in the Physician's Office (CAPO)," that explored the potential value of introducing existing medical applications (computer programs) to small primary health care settings. Ten such offices, scattered throughout the northeastern United States, were equipped with interactive terminals connected by telephone to a Boston-based computer. At each site the medical and administrative staff was acquainted with the existing applications and given the choice of implementing them "as is" or with minor modification. As new applications were developed elsewhere, they were added to the list of choices. The applications included scheduling and appointment systems, medical history questionnaires, treatment protocols, third-party billing and accounting systems, and various medical consultation programs. The medical history applications provided options such as General Medical History, General Medical Questionnaire, Acute Screening History, Insurance Questionnaire, Pediatric Allergy Questionnaire, Patient Education about Diabetes, Learning Disabilities Questionnaire, Ob-Gyn History, and Patient Education about Fertility. Some of the patient applications were available in Spanish. All applications were developed in the Meditech Interpreter Information System (MIIS) computer language, a dialect of the MUMPS language. The study findings supported some of the observations of the Missouri group and questioned others. The practices were most interested in the billing systems, although each individual practice wanted a system "modified" to suit its particular setting, a requirement that was cost prohibitive. The general practice settings found the medical history applications very useful, but the specialist settings, especially internal medicine, preferred the physician-patient encounter as a means of acquiring patient data. The limiting factor to their use in the general practice setting was cost, especially the added cost of telecommunications. The physician consultation and education applications were largely ignored (Castleman, HSM 110-71-244).

One of the primary conclusions of the CAPO study, was that such computer program applications are not likely to be effectively utilized until the state of the art enables the implementation of small, stand-alone computer systems in each practice setting. This prompted NCHSR efforts to develop the COSTAR V system discussed elsewhere in this paper. The medical practices' requirement that most of the applications be modified to meet their needs prompted the "Multi-Environment Scheme" (MESCH) under development at Washington University (Zimmerman, HS 02760). MESCH addresses the issues of the high cost associated with customizing computer applications and the difficulties of transferring applications beyond the developing institution. MESCH would operate in three phases: (1) the practice is given an opening software package which presents a menu from which selections can be made to specify and detail the particular characteristics of the practice; (2) MESCH activates a software package which designs an optimal file structure and, most importantly, creates the appropriate code required for the needed application package, producing a custom-fit package that is generated without costly programming; and (3) the application is ready to run with the same efficiency as if it had been hand written for the specific practice.

Other computer aids that are being introduced to the physician office environment include computer-assisted electrocardiography and many of the narrow-band communications applications discussed later in the section on Telemedicine. Of these, the ECG application is the most widely disseminated, and over 1,000 physician offices now routinely transmit patient ECG data to centralized computer facilities for analysis and interpretation. The sizeable library of medical application programs discussed previously in this section can also be expected to be more widely used as COSTAR and other physician-office-based, low-cost, and highly flexible computer systems begin to make their appearance in the primary care setting.

Telemedicine. Telemedicine utilizes telecommunications technology to transmit voice, data, and images between health care providers in geographically separated sites. The term was originally applied to two-way television systems that were demonstrated in the 1960's to show that it was possible to "redistribute" physicians and make more rational use of existing health care resources by centralizing scarce specialized personnel and permitting their expertise to be distributed via telecommunications and an instantaneous, as-needed basis.

Telemedicine technology involves at least three kinds of costs: (1) capital investment and equipment maintenance, (2) payment for the services provided remotely, and (3) long distance telephone charges if the two communicating sites are not in the same dialing area. Evidence to date indicates that benefits do not exceed costs. Comparing television to telephone as a backup modality for a nursepractitioner in neighborhood primary care clinics, the telephone proved to be the better modality (Moore, 1975). An analysis of two-way television to provide backup support for nursepractitioners in pediatric clinics showed that a single pediatrician would have to supervise five pediatric clinics in order for the system to "break even." In the rural primary care setting, it has been demonstrated that television is not much better than telephone for purposes of coming to a diagnostic decision (Conrath, 1975). Based on these observations, NCHSR contracted with the MITRE Corporation to determine analytically and practically what technology is needed to support an isolated nonphysician provider (Dhillon and Bennett, 1975; Doermann, 1975).

One incentive for installing telemedicine systems in rural primary care settings is to provide a sense of "community" to practitioners who would otherwise feel isolated, a major reason for the unwillingness of health care providers to practice in rural areas. The disincentives, however, are even greater. A physician can see more patients per hour and make more money by having patients come directly to his office than he can by providing teleconsults via telemedicine. In addition, there is some concern about malpractice charges and indications that insurance companies may increase the insurance premium of physicians participating in a telemedicine activity (Gravenstein, HS 01390).

Information support activity

NCHSR Information Support Activities are directed at both the Inpatient and Outpatient Support Systems described previously. For the most part these are concerned with information handling programs that assist the provider. Using large data base techniques, the provider has access to an aggregated clinical experience that he can use in forming the prognosis and selecting the appropriate treatment. With the burgeoning knowledge base in medicine, there is a need to facilitate the provider's access to that knowledge, and a variety of consultation programs have been developed that perform that function.

Databanks. In medicine, recording extensive and detailed information about the patient has long been a common practice. In fact, the quality of care has frequently been equated to the quality of records. In private practices these records provide the physician with a longitudinal profile of his patient's health and are instrumental in allowing him to provide a continuity of care that otherwise would be impossible. In the hospital setting the written record brings together the data from various sources in the hospital and provides continuity among the various providers concerned with the patient's care. Because of the way all these data are organized and the information recorded, it is virtually impossible for most physicians to systematically tap the clinical experience buried in their files, and the physician has had to rely on his memory. Retrospective studies involving hospital records required an extensive outlay of time and effort to comb the individual patient records and tease out the information desired for the study. With the introduction of computers for medical record keeping it is now possible to examine the totality of clinical experience within the file for the individual practitioner. Even more intriguing is the prospect of being able to share an aggregated clinical experience among interested practitioners in a particular area.

Almost 50 percent of the population suffers from one or more chronic diseases. Not all of these are disabling and debilitating illnesses, perhaps only 10 percent fall into that category, but it does represent a significant load on the health care system. The nature of chronic diseases is such that it requires the patient be given continuing follow-up and attention. Since disability is a frequent result of chronic illness, the economic impact of lost productivity is significant. Further, chronic diseases frequently are characterized by an insidious onset; they sometimes manifest a variety of inconsistent signs and symptoms, and progress in variable and uncertain ways. This makes the management of many chronic diseases expensive for the patient and a difficult and time-consuming task for the provider. It is only recently that investigators have developed applications of computers that allow the collection of large amounts of clinical data for analysis in ways that make it appear to the user as an aggregated clinical experience.

The initial efforts in this area were undertaken at Yale University where extensive longitudinal data were collected on patients with a diagnosis of lung cancer (Feinstein, HS 00408). By using survival as the outcome variable, certain key descriptors were identified in the data base that were of prognostic value. These descriptors then were used to identify those patients who might benefit from surgical intervention and those who definitely would not. Based on these concepts, other databank efforts were undertaken. One of these, the rheumatic disease databank established at Stanford University, contains data on over 4,000 patients with various rheumatic diseases such as rheumatoid arthritis, lupus, scleroderma, and juvenile rheumatoid arthritis (Fries, HS 01875). The groundwork for this effort was developed by the American Rheumatism Association by sponsoring a cooperative effort to arrive at a common vocabulary, terminology, and criteria. A databank established at Duke University contains clinical information on some 2,000 patients with coronary artery disease and myocardial infarction, including all of the history, signs, symptoms, laboratory tests, exercise electrocardiograms, catherization laboratory data, and progress notes obtained in the course of the patients' clinic visits (Rosati, HRA 230-76-0300). This information is analyzed to assist the physician in making the choice between treating the patient medically or treating him surgically. The system picks out all patients in the databank who are similar to the one currently under treatment and presents the information in tabular form. The physician then is in a position to contrast the outcomes of the patients in the two groups, surgical vs. medical, in terms of survival, freedom from pain, and restoration of function. It allows both patient and physician to consider all of the pertinent factors before making important treatment choices. The project has been successful in identifying subgroups of patients whose survival would be increased by surgery and subgroups where surgery and medical treatment seem to make no difference in survival. An interesting additional finding of this research has been the identification of a group of heart attack patients who can be safely discharged from the hospital after only seven days stay, some eleven days less than the national average. Ultimately, databanks can be expanded and extended to the point where a national Chronic Disease Information System may become feasible.

Computer based consultation. The sheer amount of knowledge (information) required to appropriately care for patients is rapidly becoming greater than the memory capability of most physicians. Computer-based consultation systems are being developed which use the computer to gather, store, and process medical/clinical data for the specific purpose of supporting and a[illegible]g in direct patient care. These activities tend to fall into two general categories: systems which monitor adequacy of care (e.g. detection of potential drug-drug interaction) and systems which suggest diagnostic procedures and therapy. Some systems do both. An example of a project which monitors patient care is the MEDIPHOR system developed at Stanford University (Cohen, HS 00739). This system detects potential drug-drug interactions *before* the drug in question is dispensed. The system creates an advisory which, depending on the severity of the interaction, is placed in the patient's medical record or is sent directly to the attending physician. The advisory also contains consultative information in the form of suggested drug alternatives, dosages, and routes of entry. The MYCIN system, also developed at Stanford University (Cohen, HS 01544), serves as an example of a strictly consultative system. Using a rule-based approach, commonly referred to as artificial intelligence, MYCIN "acts" like an expert in infectious diseases. The system queries the physician to obtain patient clinical information and, as more information is gathered, makes (and updates) recommendations on what the unknown organism may be and what the best choice of antibiotic is based on the current completeness of the patient data base (results of bacteriological tests and other dianostic related information). The system has other rather unique and useful properties in that it can easily be "educated" by adding rules and it will, when so instructed, go through the logic of its recommendations step-by-step, making it a powerful teaching tool.

User acceptance of such systems is an important concern and one that is currently under evaluation at the Beth Israel Hospital (Bleich, HS 00188). Despite the excellent clinical performance of the Electrolyte and Acid-Base Program, physician utilization of the program has been disappointingly low, especially in the better staffed urban hospitals. Usage increases after implementation in smaller hospitals, but only temporarily, indicating that the major use of such systems is educational. Too many busy physicians have been deterred by system interface requirements on their time, attention, and mode of dialogue, a problem that is not likely to be solved until more acceptable ways of interfacing with the system are developed.

The HELP system at the University of Utah uses a different consultative approach (Warner, HS 01053). This system has access to a variety of patient information, including history, clinical laboratory tests, physiological parameters (when the patient is in the ICU), nurses' notes, and X-ray results. As information is accumulated, various computer programs (HELP sectors) come into play, creating monitoring and consultative information along the way. Normally the system is passive in that it waits for the physician to query HELP and then makes available whatever diagnostic and therapeutic information the data base has created in the HELP sectors. The PROMIS system at the University of Vermont uses an opposite philosophy and "guides" the physician throughout the course of the care process, using a highly structured, interactive program (Weed, HS 00175). The monitoring and diagnostic/therapeutic consultative information is presented to the physician during the course of interacting with the system, insuring that the physician is aware of the consultative information. Acceptance of all these capabilities to assist the physician in the case of his patients is growing. One problem which is developing is how to maintain and update the growing number of rather extensive data bases (e.g. drug-drug interaction, medical care guidance frames, and acid-base consultations). It may soon be necessary to designate and organization(s) to be responsible for validating and maintaining these data bases.

Special Hardware. In many information system applications, there is a need to retrieve from the computer a series of frames of information. For the most part these frames require little or no computation time but are simply a transmission of formatted frames from the computer's disk storage to the terminals. Accessing these data and transmitting them to the terminals can cause an excessive burden on he computer system and seriously degrade response times. One solution to this problem, under development at Washington University, St. Louis, will employ wide-band communication techniques to support a patient-based computer-assisted interview history (Molnar, HS 01533). This new approach uses a cable television distribution network to broadcast questionnaire information continuously and repetitively from a centralized data store. These "data bursts" contain complied instructions similar to those developed for the computer-assisted instruction author languages, and are complete with display frames, branching instructions, and the necessary calculations to process one CRT screen of information. The project objectives are to develop an efficient system for questionnaire administration, to demonstrate the technical and medical feasibility as well as the economic possibilities of a broadcast-based automated system for history gathering, and to develop appropriate terminals for use in such a broadcast scheme. The development of the special transmitter and receiver hardware required for the system has been completed.

Another hardware innovation supported by NCHSR is the interface and control for a Graph-pen sonic digitizer (Rosati, HRA 230-76-0300). In the coronary artery disease data bank project at Duke University, there was a need to convert the X-ray angiogram images into a form that would allow them to be analyzed by the computer for determinations of volume and normality of contraction. While the Graph-pen sonic digitizer was commercially available, it had to be modified to allow it to run simultaneously with the other users of the computer. An interface was designed that transferred the burden of control of the Graph-pen from the central computer to a local microprocessor while at the same time improving the efficiency of transmission of the digitized data.

Technology transfer

The diffusion of technological innovations within the health care system is a problem of sufficient magnitude to justify its coexistence with other issues. The public is made acutely aware of technological failures, where, for example drugs, IUD's gastric freezing techniques, radical mastectomies, and oral treatment for diabetes perhaps were disseminated too rapidly. The public is equally made aware that high costs may be associated with technologies such as the Computerized Tomography (CT) Scanner.

On the other hand, innovations with proven benefit to the health care system and having high utility potential, such as computerized physician consultations (Bleich, HS 00188) and computer-stored medical record systems (Barnett, HS 00240; Weed, HS 00175) represent technologies whose application lags, in part because of the absence of educational transfer policies. Reduction of the lag time between development of an effective innovation and its availability to the provider for subsequent benefit to the consumer of health services is viewed as having a facilitating effect on the resolution of other major health care issues, such as productivity and access, cost containment and financing, and quality assurance and improvement. Any strategy that would attempt to affect this lag time must include the development of improved mehodologies for the study of the process and outcome of technology transfer in the context of organizational structures, industrial incentives, and the role of user's groups in influencing the rate of diffusion as well as the cost and maintenance of the technological innovation.

Such methodologies have been applied only recently as in the current Technology Assessment (TA) of Computerized Tomography (CT) Scanners. In this TA, health planners, providers, and researchers are seeking to learn, as early and as precisely as possible, the impact of this technological innovation on human health, the cost and effectiveness of health care, and the allocation of national health resources.

Until recently NCHSR program activities in technology transfer have emphasized the following: (1) the government's role in providing incentives to the technology transfer process such as user groups (Zimmerman, HS 01540), system performance certification (Hsieh, IAA 0003), standardization (O'Neill, IAA 730001) and technical assistance programs (Hsieh, IAA 0003); (2) increasing the knowledge base on the value of information dissemination (Lave, HS 02122); and (3) the development of new technologies, such as the MESCH system for customizing computer applications (Zimmerman, HS 02760), which enhances the exportability of other, newly emerging technologies. These activities are in addition to the many demonstrations and evaluations of new technologies being conducted, the several surveys and state-of-the-art studies of deployed or emerging technologies, and the numerous technology conferences and publications initiated by NCHSR, all of which partially address the dissemination issue.

Two NCHSR technology project areas which had as a primary objective the facilitation of technology transfer were computer-assisted electrocardiography and the MUMPS computer language. Both had strong elements of user group participation in product development and both relied on centralized resources for software reproduction, maintenance, and distribution. Both also included procedures for product standardization and certification as well as a mechanism for technical assistance during the adoptee's implementation phase.

In 1968 NCHSR assumed responsibility from a predecessor organization for an intramurally developed electrocardiogram (ECG) analysis system (ECAN). At that time the technology had been demonstrated, under laboratory conditions, as being capable of accurately performing the cardiologist function of measuring the ECG wave and providing an interpretation. A prototype system, with the cooperation of 30 remote hospitals and clinics, was processing over 50,000 ECG's per year. During this same period comparable systems were under development at the Washington Veterans' Administration Hospital, the Mayo Clinic, and the IBM Corporation. None of these systems had been deployed or implemented by a health care facility as part of its routine fee-for-service operation.

The NCHSR program to initiate such a transfer was the first. It began with the 1969 contract to St. Luke's Hospital in Denver to demonstrate the feasibility of such systems to process the ECG's of an inpatient population for a large region. By 1973 all of the over 20 participating hospitals had elected to continue the services on a fee-for-service basis (Elliott, HSM 110-69-414). Physician feedback from the Denver project was used to improve the system's performance (Sandberg, HS 110-72-077) and formalize a user's group (Hsieh, IAA 003).

Over 400 tape copies of the ECAN source code were disseminated, and adopting institutions were encouraged to participate in a data pool strategy that provided technical assistance and leading to certification of the program's performance in the adoptee's environment (Barnes, 1976). Awareness of the technology was sustained by participation of the professional societies (Dreifus, 1978) and efforts to promote standardization of ECG criteria and diagnostic terminology (Cole, 1975).

By 1975 over 4 million ECG's were being computer-processed annually, providing services to approximately 2,000 hospitals and an equal number of ambulatory care settings (Drazen, 1972). Most of this volume is processed telephonically by fewer than 20 national or regional ECG service bureaus. The three largest companies, which account for over one-third of the total number of computer-processed ECG's, all initiated their services using the NCHSR ECAN program. These three organizations have since applied their own research and development funds to either enhance ECAN or produce their own proprietary programs. Most of the other service bureaus and virtually all of the institutions that process ECG's only for their own facility lease the IBM program, which is continuously being updated and improved. The Mayo and the Veterans' Administration programs have had little impact beyond their developing institutions. Although NCHSR still receives and fills frequent requests for ECAN documentaion,, it no longer supports program enhancement.

MUMPS, the computer language and operating system developed at the Massachusetts General Hospital (Barnett, HS 00240), has followed a technology transfer course similar to that of computer-assisted electrocardiography. The power of the language to facilitate medical information processing needs was demonstrated initially at the Harvard Community Health Plan and the language was quickly emulated. By 1972 there were eight dialects of the language in use throughout the country (Johnson, 1972). Literally hundreds of medical applications were being developed, a dozen or more supported by NCHSR, and many more by the growing number of institutions that as part of their shift towards minicomputers had adopted MUMPS as the language of choice.

The transfer of applications between institutions which used different dialects was a difficult, expensive, and time-consuming procedure (Lucas, 1976). In 1973 NCHSR initiated an interagency agreement with the National Bureau of Standards to develop a strategy for standardization of the language (O'Neill, IAA 730001), an effort which culminated with the 1977 announcement that "The MUMPS Language Standard" had been approved by the American National Standards Institute (ANSI). The MUMPS Users' Group, established in 1974, contributed to this acceptance through its programs to establish a central resource for all MUMPS documentation and to facilitate the exchange of information between both individual and institutional users (Zimmerman, HS 01540). Upon the 1976 termination of NCHSR funding for the standardization effort, the MUMPS Development Committee, composed of over 50 volunteer participants, elected to continue its responsibilities for maintaining and enhancing the proposed standard. Likewise in 1977 the MUMPS Users' Group became an incorporated, not-for-profit enterprise.

Appendix A. Technology program projects supported by NCHSR*

Abrahamson, S.; HS 00020; University of Southern California; "Evaluation of Computer Controlled Patient Simulator."

Barnhard, H.; HS 00525; University of Arkansas Medical Center; "Diagnostic Radiology Information System."

Barnett, G.; HS 00240; Massachusetts General Hospital; "Hospital Computer Project."

Barrett, J.; HSM 110-73-331; Battelle Columbus Laboratories, "An Evaluation of the Impact of the Implementation and Operation of the Technicon Medical Information Systems at El Camino Hospital."

Bellville, J.; 00146; Stanford University Medical Center; "Demonstration of Computer Monitoring."

Behrendt, T.; HSM 110-69-185; Jefferson Medical College of Philadelphia; "Television Opthalmoscopy Development: Feasibility Testing for Geometric and Temporal Studies."

Billmeyer, D.; HS 01202; Physicians Association of Clackamas County; "Implementation of a MUMPS System to a Decentralized HMO."

Binnings, G.; PH 86-68-191; Aerojet General Space Division; "Streptococci Detection, Develop Automated Methodology."

Bleich, H.; HS 00188; Beth Israel Hospital; "Automation of Medical Consultation."

Bruce, R.; HS 00092; University of Washington School of Medicine; "Computer Diagnosis of Cardiovascular Disease."

Brunjes, S.; HS 01577; Yale University School of Medicine; "Quality of Care and an HMO Automated Medical Record."

Castle, C.; HS 01481; University of Utah; "Salmon-Challis Medical Communication Project."

Castleman, P.; HSM 110-71-244; Bolt, Beranek and Newman, Inc., "Evaluation of Automated Medical History and Development of Other Computer Applications in the Medical Practice Setting."

Clark, G.; HS 00427; University of Tennessee School of Medicine; "Computer Techniques in Patient Care."

Cloutier, R.; HSM 110-69-409; Berkeley Scientific Labs.; "A Study of the State of the Art Laboratory Automation."

Cohen, S.; HS 00739; Stanford University; "A Computer-Based On-Line Drug Therapy Monitoring System."

Cohen, S.; HS 01544; Stanford University; "Computer-Based Consultations in Clinical Therapeutics."

Cole, S.; HS 02603; Engineering Foundation; "Computerized Interpretation of the ECG-II." (Conference)

Collen, M.; HS 00288; Kaiser Foundation Research Institute; "Health Services Research Center."

Coriell, L.; HS 00130; Institute for Medical Research; "Evaluation of Hospital Clean Rooms".

Cox, J.; T01 HS 00074; Washington University School of Medicine; "Technology in Health Care." (Training Grant)

Cronkhite, L.; HS 00113; Children's Hospital Medical Center; "Control of Operations by Scheduling Using Terminal."

Davis, E.; HRA 230-77-0112; Visiting Nurse Association of Vermont; "Demonstration of a Computerized Decision Support System in a Nurse Practitioner Staffed Rural Health Clinic."

DeBakey, M.; HSM 110-69-237; Baylor University School of Medicine; "Small Computer Network for Monitoring the Critically Ill."

DeNavarez, F.; HSM 110-70-346; Medical and Health Research Association of New York City, Inc.; "A Preliminary Demonstration of Automated Sputum Cytology for Mass Screening."

Drazen, E.; HRA 230-75-212; Arthur D. Little, Inc.; "Impact and Diffusion of a Technological Innovation for Health Care—A Study of Automated ECG Systems."

Dreifus, L.; HRA 230-76-0166; The American College of Cardiology; "Optimal Electrocardiography." (Conference)

*Note: See Selected Bibliography for National Technical Information Service (NTIS) PB numbers in order to obtain reports.

Dunn, D.; HS 01132; Iowa Hospital Association, Inc.; "Long-Term Care Component—Iowa Health Data System."

Edmunds, H.; HS 01467; University of Pennsylvania; "Evaluation of Computer-Aided Care After Heart Surgery."

Edwards, S.; HSM 110-70-368; Good Samaritan Hospital; "Demonstration and Evaluation of the Shared Modular Hospital Information System."

Elliott, R.; HSM 110-69-414; St. Luke's Hospital Association; "Demonstration and Evaluation of a Community Hospital-Based Computer Assisted Electrocardiographic Interpretation Service."

Evans, J.; PH 86-62-213; George Washington University; "Coronary Care Unit Patient Monitoring, Research and Development."

Feinstein, A.; HS 00408; Yale University School of Medicine; "Improvement of Methodology for Clinical Evaluations."

Fifer, W.; HS 01591; Interstudy, Inc.; "Innovative Technology in a Rural Health Care System."

Frazier, W.; HS 02149; Yale University; "Validation of Quality Assessment Measures in EMS."

Fries, J.; HS 01875; Stanford University School of Medicine; "Computerized National Chronic Disease Databank System."

Gall, J.; HSM 110-71-128; El Camino Hospital; "Demonstration of an Existing Hospital Information System."

Gall, J.; HS 02027; El Camino Hospital; "A Patient Care Quality Assurance System."

Gardner, R.; HS 02463; Latter-Day Saints Hospital; "Computerized Protocols Applied to Emergency Care."

Garrett, R.; PHS 108-66-299; Tulane University; "HIS, Optical Input/Output Recording."

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Gravenstein, J.; HS 01390 & HSM 110-72-383; Case Western Reserve University; "Laser Mediated Telemedicine in Anesthesia."

Gustafson, D; HS 00316; University of Wisconsin; "Medical Diagnosis Using Subjective Probabilities."

Habig, R.; HS 00473; Duke University; "Improvements in Automated Clinical Chemistry."

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Komaroff, A.; HS 02063; Beth Israel Hospital, Harvard Medical School; "Cost-Effective Strategies in Ambulatory Care."

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Lindberg, D.; HS 00014; University of Missouri Medical Center School of Medicine; "Computer Recognition of Human Disease Patterns."

Lindberg, D.; HS 02569; University of Missouri; "Health Care Technology Research Center."

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Lucas, F.; HS 01571 & HS 110-72-119; University of Missouri; "Automated Physician's Assistant."

Maronde, R.; HS 00084; University of Southern California School of Medicine; "Digital Computer and Patient Care: A Pilot Study."

Marshall, C; HS 01392; Mt. Sinai School of Medicine; "East Harlem Broadband Health Communications Network."

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Pickett, R.; HRA 106-74-180; Bolt, Beranek and Newman, Inc.; "Demonstration of a Method for Improving the Performance of an Ambulatory Clinic through the Planned Application of Technology."

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