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FACTORS INFLUENCING ADOPTION AND USE

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

ACCEPTABILITY TO MEDICAL CARE PROVIDERS

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

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

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

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

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

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

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

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

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

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

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

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

TECHNICAL TRANSFERABILITY

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

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

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

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

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

TMIS is already installed in six hospitals, including research and teaching institutions. In addition, activity is underway to make TMIS available to hospitals in modular form. The business office subsystem of TMIS can already be purchased

separately. Although the basic system would still include computerized patient records, such capabilities as reporting results from the laboratory and radiology departments and plans for nursing care, could be excluded. These functions would be available as options that could be added to the core system at any time elected by user institutions.

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

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

COST

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

Medical Information Systems in Hospitals

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

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

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

Startup costs vary widely because many financial arrangements between hospitals and vendors are possible (2). Hospitals can lease or lease-purchase equipment and pay for an agreed upon list of services on a monthly basis. Computer hardware can be installed onsite, or the hospital can share the services of a central computer facility. Hardware and software can also be purchased under long-term financial

arrangements. Either the institution or the vendor can employ technical support staff for the computer. One large hospital (over 500 beds), which purchased hardware and software, had initial costs of $2.5 million (2). Implementation costs in a medium-sized hospital, including physical installation and site development, for the Technicon system were reported to be about half-a-million dollars (24).

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

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

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

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

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

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

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

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

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

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

Medical Information Systems for Ambulatory Care

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

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

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

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

system. The study suggested that such a medium-sized group practice could support a capital investment for physical equipment in the range of $275,000 to $460,000.

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

Cost Effectiveness

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

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

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

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

GENERAL FACTORS

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

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

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

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

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

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

Federal policy and economic factors will also impinge on the adoption of medical information systems. Managers of medical care institutions will consider general economic constraints and incentives in determining their need for a computer system. Government could encourage or discourage use through reimbursement policies and Federal and State regulations concerning capital expenditures. Direct Gov-

ernment intervention, as well, can be an effective tool influencing the diffusion process (36). Finally, market forces such as competition, profitability, and consumer demand will be important determinants of the time lag between the introduction and final adoption of a new technology (46).