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BACKGROUND

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

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

CAPABILITIES

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

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

Meeting all of these needs places extensive technical demands on a medical information system (8). Providers of patient care require data quickly. Medical information systems can meet this requirement only if patient data files are stored within the system and computer terminals give medical users immediate access to these files. In such a system, described technically as "on-line," computer terminals are connected directly to the computer's central processing unit, which calls in and processes data stored on computer tape or disks as required. In order for data to be easily available, multiple computer terminals need to be located in all areas where data

about patients are entered and used (see figure 1). To provide information for physicians and administrators making decisions, the computer system must be able to quickly manipulate and analyze data in many ways helpful to them. Satisfying this requirement calls for careful structuring and definition of the data base as well as sophisticated software. Finally, researchers need a medical information system with capacity to store massive amounts of data on large populations for long periods of time.

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

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

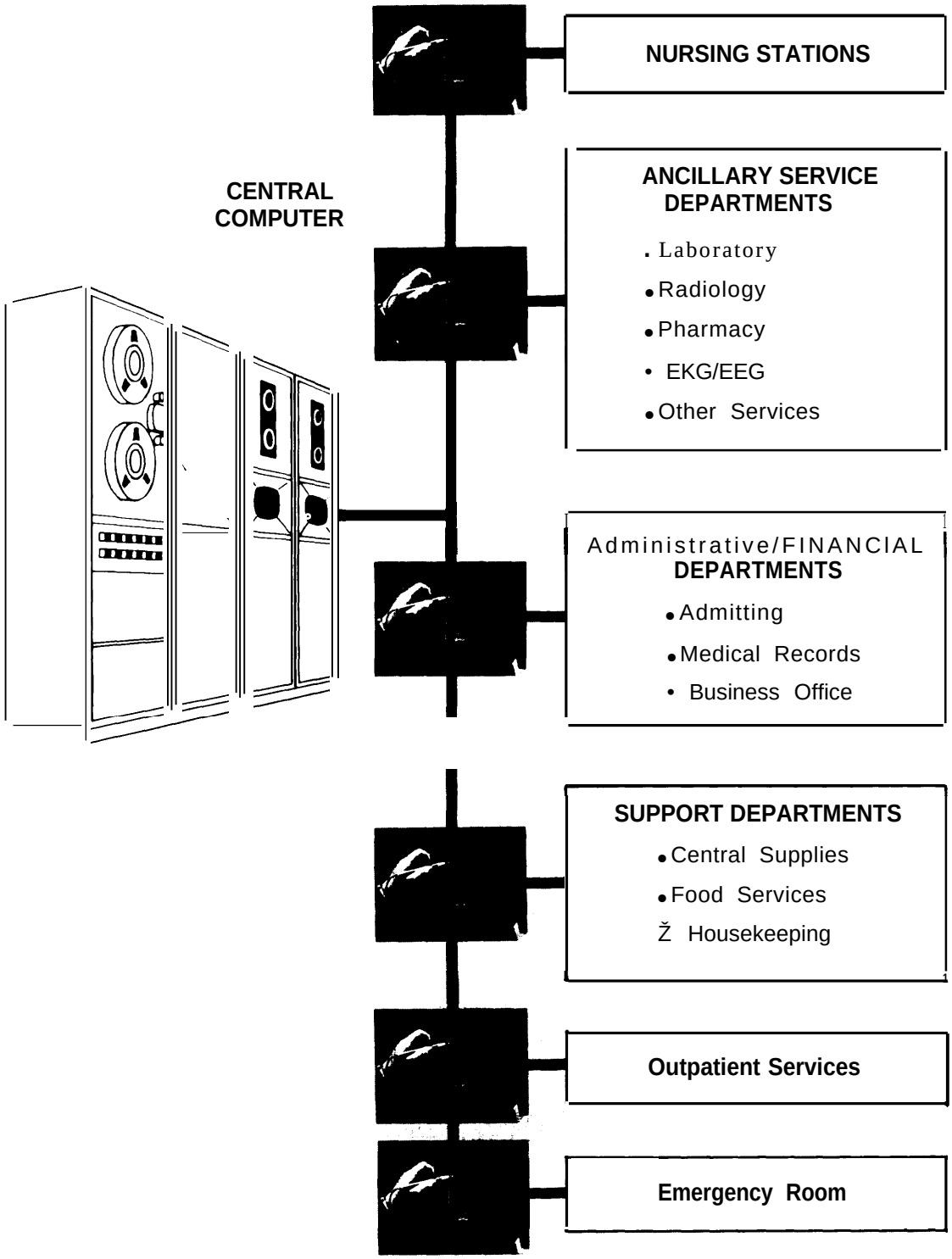
Medical information systems vary, however, in such technical aspects as use of large or minicomputers, location of the computer onsite or shared computer services off site, data entry and retrieval devices, storage of data in the system, and programing language. Other variables include who enters and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

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

DEVELOPMENT AND SUPPORT

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

Figure 1-HOSPITAL DEPARTMENTS WHERE COMPUTER TERMINALS ARE LOCATED



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

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

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

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

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

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

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

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

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

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

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

lishment in **1969,** NCHSR has spent a total of $26.6 million for projects relating to medical information system s.*

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

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

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

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

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

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

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