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# Review Paper

## *Hospital Information Systems: A Review in Perspective*

**Abstract**: The demand for information for health care is increasing exponentially in volume, content and the number and geographical distribution of users. Most HIS systems commercially available today are based on designs and philosophies of the 1970s. Even though new technology has improved these systems' performance, to meet current demands, concepts must be shifted from the paper-driven system to an electronic system in which the patient is the focus. We need a merger of the functionality of existing systems along with new functionalities and a computer-based patient record. These new health care information system must have no boundaries; data collection must permeate all locations at which a patient receives care, and seamless linkages must connect all individuals who contribute to that patient's care. Even though systems are being designed today to meet these expanded informational requirements, we will not see such systems in use before the next century.

***Keywords***: Hospital Information Systems, Computer-based Patient Record, Departmental Systems

## Introduction

The introduction of the computer into the hospital setting to assist in the handling of the vast volumes of data seems natural enough and, in fact, computers were introduced into this environment in the 1950s. Progress was slow and hindered with some rather spectacular failures. Even today, the expectations and, in fact, all of the necessary functionality still does not exist for hospital information systems. During this same period we have seen exponential increases in computing power and in communications technology; healthcare applications have failed to keep pace. Why? Perhaps two reasons explain this failure: (1) the health care delivery system is one of the most complex and pervasive systems in industry; and (2) the vast variety and professional credentials of individuals who must understand and use the system to make it work.

At an International Medical Informatics Association (IMIA) Working Group 10 workshop on Hospital Information Systems in 1988, Dr. Morris Collen stated that the goal of a hospital information system should be to "use computers and communications equipment to collect, store, process, retrieve, and communicate relative patient care and administrative information for all activities and functions within the hospital, its outpatient medical offices, its clinical support services (clinical laboratories, radiology, pharmacy, intensive care unit, etc.), and with its affiliated medical facilities, Such an integrated, multi-facility, medical information system should have the capability for communication and integration of all patient data during the patient's service life time, from all of the information subsystems and all facilities in the medical system complex; and to provide administrative and clinical decision support" [1].This statement is important because it recognizes that clinical information is not the property of a single facility but rather is part of a global resource which focuses on the patient-centered record.

Computer applications in the hospital setting have developed along functional lines: billing, admission/discharge/transfer (ADT), order entry, result reporting, laboratory, pharmacy, and radiology. The exchange of data among functions was mainly a manual process, if it were done at all. Most applications were developed on dedicated computers, most processes were batch-oriented, and most users were neither the creators nor users of data.

Over the years, the names applied to these application systems have varied and include Hospital Information Systems, Clinical Information Systems, Medical Information Systems, Management Information Systems as well as application-specific systems: Laboratory Information Systems, Pharmacy Information Systems, Radiology Information Systems, etc. Even now, as we try to shift the focus from an event-driven HIS to a patient-centered electronic health record system, the words we use to name the new concept are confused: computer-based patient record, electronic health record, computerized medical record. Those terms mean everything from a billing document to a fully functional system which includes all data created about a patient anywhere by anyone along with the full functionality to support the optimal use of the data for patient care. In my opinion, the term Hospital Information System is now outdated. Its replacement name, perhaps a health care information system, must embrace the concepts defined by Dr. Collen.

This paper discusses the early years of HIS development and traces that development to today's commercial systems. The paper then shifts direction to describe the functional and data requirements of a hospital information system. The paper then extends these requirements to deal with the needs of today and the next generation healthcare information infrastructure.

## The Early Years

In 1958, the American Hospital Association (AHA) conducted a feasibility study for the use of computers in the hospital. This study produced three general findings which influenced the evolution of Hospital Information Systems over the next decade. These findings stated:

1. Hospital business office functions should be the principal focus of any computerization.
2. A large, general purpose computer should be used rather than smaller, special-purpose computers.
3. The use of remote terminals for the input of data was not only economically infeasible but undesirable because they would complicate the ordering of services and supplies.

In 1962, an AHA-survey found that 39 hospitals were using computers [2]. The study was repeated in 1972 and found that this number had increased to 2,887 hospitals using computers in some manner. In 1976, another AHA survey found that the number of hospitals using computers had increased to 5,734 with 3,983 hospitals having in-house computers which were rented, leased or owned. In 1983, approximately 90% of the hospitals were using computers, and in 1994 virtually all hospitals have at least some type of computing.

The use of the computer in the business office represented tasks that were easily computerized and costs could be most readily justified. The use of the computer, particularly in batch-mode operation, was non-threatening - at least to healthcare professionals - since it was viewed and used as a super-sophisticated adding machine. Tasks computerized included inpatient billing, accounts receivable, accounts payable, general ledger, payroll, inventory, and various canned management and financial reports. Most hospitals today still support these activities on a large mainframe computer as a separate activity from other computer applications. In many cases, administrative computing is managed separately from clinical computing. Data entry, in far too many cases, is manual in spite of the fact that the same data may exist electronically in other systems. The green-eye shade mentality of the pre-1950s is carried into the 1990s.

In the early 1960s, several groups - some commercial organizations working with hospitals and others academic - undertook the development of computerized systems for the handling of patient information. These early systems were classified into two categories. Level I systems provide for data collection and message switching capability. These systems transmit orders, capture charges, and report results. Functions were grouped into data collection, data communication, and data storage. Level II systems were designed to handle clinical information as well as requisitions.

Most major computer companies, such as IBM, Burroughs, Honeywell, General Electric, Control Data, and NCR, seeing the potential of significant sales in this market, were active in support of HIS development. Industries with experience in using computers in complex applications joined in. Companies include Lockheed (Technicon), Burroughs (Medidata), McDonnell Douglas (McAuto), National Data Communications (REACH), and Martin-Marietta [3-5].

Most of these early systems were resounding failures. Of the above systems, only Technicon exists today. In addition to underestimating the complexity of the information requirements, users were not involved at an adequate level in the design and, in fact, were not prepared to use computers. Hardware and software tools were also inadequate, and some vendors altered operating systems and wrote their own programming languages in an effort to circumvent these limitations.

In 1969 Feinstein [2] noted that while computers had been applied effectively in situations where a standard mechanism already existed for dealing with the data, computers had not yet had an important impact on the more inherently clinical features of medical strategy and tactics - a statement that can be made of many computer applications today. Development of HISs was a factor of technology: hardware and software; people: developer and user; and economics. Estimates on the costs of information handling vary between 25% and 39% of the total cost of health care [6]. Most medical informatics professionals agree that a reasonable cost for the electronic information handling is at least 2-3% of the operational budget for an institution.

As technology advanced, developers learned to appreciate the complexity of the problem and began to address smaller, well-defined components of the overall system. By early 1970, some of the early developmental efforts became commercially available. The Technicon system, begun by Lockheed in 1964 became the most successful application. Development of this system required over 10 years and cost approximately 25 million dollars. During its first year of operation, more than 2000 changes were made to the system. Many of these changes affected the appearance of things such as reports.

As previously noted, the early systems were developed on large, centralized mainframe computers. Both development and operation of systems were controlled by the data processing staff, usually an independent staff. The goals of early systems were to reduce cost and improve patient care. Since the later goal was rather nebulous and not amenable to outcome studies, systems were motivated by an effort to reduce costs. The result was a concentration on accounting and the financial aspects of patient care. Because of the expense and lack of trained computer personnel, shared systems (such as SHAS) became popular in the late 1960s and still persist although decreasing in numbers.

Shared Medical Systems developed one of the most effective implementations of a financial system. Initially, all data were electronically transmitted to a central location for processing and results returned. Later implementations were based on in-house computers. Similar operations were provided by IBM's SHAS and McDonnell Douglas's McAuto systems. During the 1970s, the question often discussed was shared systems versus an in-house system.

In the late 1960s and into the 1970s, the patient care aspect began to be accommodated into system design. These systems were truthfully still Level I systems, although they were suggested to be Level II systems. The hardware emphasis moved from batch-oriented systems to interactive systems. Again, these systems were based on the large mainframe computer and were the order/entry result reporting model which worked either in conjunction with or in concert with the financial package. Technicon's MIS and IBM's PCS are the classic examples. The significant costs of these systems limited the implementation to those larger facilities who could afford the hugh financial commitment to purchase or lease these systems. At least for the service-oriented tasks, these systems worked for those organizations having the resources: people, equipment and dollars. These patient care systems were largely designed to speed up the process of message switching. Events which were now performed manually were computerized. Little thought was applied to the concept that there were now different ways in which some of the tasks could be performed.

With the emergence of the minicomputer in the 1970s, specialized departmental systems were developed. These systems performed a well-defined set of tasks associated with an area such as a lab or a pharmacy. Costs were less, and therefore more people could afford such systems. The disadvantage of such systems was mainly that they were uncoupled from other systems. As networking technology was introduced in the 1980s, a second approach for the development of an HIS appeared on the scene. Simborg's STATLAN is an excellent example of this approach. Communications among systems is supported by a Local Area Network running on a broadband channel. Each module on the network is interfaced to all other modules. The linkage between departmental systems is accomplished through data request and data response. One module transmits a message to another module requesting, for example, a lab result. The second module is programmed to accept such a request and then respond by transmitting a second message returning the data. Complete HISs have been proposed based on this approach using the term "virtual database," implying that the database may reside in several departmental modules on the network.

A major problem of such an approach is that the strength of the total system is only as great as its weakest link. Smooth data flow depends on the response of each module in receiving and responding to data requests. Reliability of data, timeliness of update, response to changes, and duration of data retention are issues of concern.

A detailed look at one of these systems may be enlightening -the Technicon system [7,8]. This system had its origin in the Lockheed Corporation in the early 1960s. Sensing a need to diversify from a producer of missiles and aircraft and satellites, Lockheed made the decision to exploit its experience with computers and communications by applying it to hospitals. The Lockheed Information Systems Division was formed in 1964 with the objective of applying spaceage technology to solve a hospital's information flow problems. In 1966, this group assisted the Mayo Clinic in identifying its computer requirements and those of two related hospitals. Although the results of this combined effort were never funded and implemented, the engineers gained adequate experience to undertake an independent development of a hospital information system. Returning to their hometown of Sunnyvale, California, the Lockheed ISD group convinced management to fund the development of an MIS. El Camino Hospital in nearby Mountain View agreed to serve as the development site. In 1971, development had proceeded to the point that a contractual agreement was entered into with El Camino. At this time Lockheed encountered difficulties in other areas of the corporation and set about finding a partner for its emerging MIS.

The Technicon Corporation was interested in expanding beyond its automated clinical laboratory and purchased the system developed by Lockheed, naming it the Technicon Medical Information Systems Corporation. During the next several years, development continued on a rather rocky road to obtaining physician support for the system. In 1974, physician acceptance and measured cost savings resulted in a new contract with El Camino, and now the system was firmly in place.

During this period, the National Center for Health Services Research funded the Battelle Columbus Laboratories to conduct an independent evaluation of the MIS. This review, one of the most comprehensive reviews of an HIS ever conducted, was generally favorable.

As interactive use of the system increased, Technicon was faced with response-time problems. Technicon met this challenge by modifying the IBM operating system and integrating the characteristics of the operating system into their application design. This approach proved to be an ultimate liability as hardware and software technology provided greater and more effective interactive capability.

In 1972, the same system was implemented at the Ralph K. Davies Medical Center in San Francisco and in 1973 at the Nebraska Methodist Hospital in Omaha. In 1975, after several other installations, the Technicon MIS was installed at the Clinical Center of the National Institutes of Health. Currently, over 100 Technicon systems are installed throughout the world.

Europe has contributed significantly to the development of HISs. The J5 system developed in Sweden at the Karolinska Hospital in the mid 1960s [9] was one of the most advanced systems of its time.

The Kings Hospital computer system [10], the London Hospital system [11], the University of Hannover Hospital project [12], and the Danderyd HIS [13] are noteworthy for early contributions. The DIOGENE Hospital Information System [14,15] has undergone several evolutions and continues to be an impressive system. The BAZIS HIS [16] and the work of numerous groups in Europe and Asia continue the development of HISs.

The HELP system, developed at the LDS Hospital in Utah by Dr. Homer Warner and his group [17] is commercially available today from 3M. More recent systems include work of Bleich, Slack and Safran at Beth Israel [17] and the development work at Columbia-Presbyterian in New York by Dr. Paul Clayton and his colleagues. The Duke Hospital Information System (DHIS) is a comprehensive hospital information system developed in-house, beginning in 1975. Major functions including nursing care and medication administration reports, patient admission/discharge/transfer, order entry/result reporting, message communication, medical record abstract and case mix analysis, specimen/X-ray/document tracking, and automatic charge capture. The system utilizes the IMS database structure and the CICS interactive terminal handler. Applications program code is independent of data location within the database structure. Data are identified by name rather than by location and obtained from a common data pool or symbol table. It is, therefore, possible to reorganize the database without rewriting applications programs. Items such as screen content, screen sequence, and the order in which data must be collected are treated as data elements and are changeable without the involvement of an experienced programmer. DHIS was initially implemented in October 1976 and established a terminal network connecting all nursing stations, the outpatient clinics, specimen laboratories, and service departments. IBM subsequently marketed this system as PCS until the late 1980s.

Dorenfest [19] does an excellent job of identifying current commercial HISs and where they are in their life cycle. Mid-life cycle systems include TDS, SMS, HBO, IBAX, AMEX, MEDITECH, FIRST DATA and GTE. Early life cycle systems include Bell Atlantic, PHAMIS, HDS, 3M HELP, Cerner, and AMERITECH KDS. The ultimate success and survivability of many of these systems still remains to be seen.

## Scope and Functionality of A Hospital Information System

Today's hospital information systems grew out of developmental work that took place during the 1970s. Functional specifications, system design, and technology selection were driven by the immediate problem at hand. Three general classes of systems resulted from this methodology.

Hospital information systems were designed to deal primarily with the problem of moving transaction-oriented data throughout the institution. The type of functions which were developed included admission/discharge/transfer (ADT), order entry/result reporting, and charge capture. In most cases, the systems were controlled by administrative and financial personnel who had responsibility for the accounting systems. Interaction between health care providers and the HIS was, with a few exceptions, limited to batch printed reports such as cumulative laboratory summaries and nursing care plans. Mainframe technology was utilized as the best hardware platform for providing an extensive network.

The reduced cost afforded by minicomputer technology in the 1970s led to the development of departmental support systems, such as laboratory information systems, radiology information systems, and pharmacy systems. Priority was given to functions which would enhance the efficiency and management of the service department such as worklist management, instrument interface, inventory and quality control. These systems were separate from the institutional system with control remaining with the department. While such systems improved the level of information management support available at the department level, the department had to also assume the cost of all data entry, much of which was redundant. For example, laboratory personnel had to shoulder the overhead of admitting patients to their system to be able to take advantage of its benefits.

Clinical information systems designed to support the health care provider grew up mostly in ambulatory clinics or sub-specialty areas. This origin was ideal because of the limited knowledge domain required of the system and the restricted amount of data available about any one patient. Priority was given to manipulating the patient's clinical record and to clinical staff. Control rested with the interested clinical staff. First minicomputers, and later microcomputers, were used as the hardware platform for these systems because of their interactive capabilities.

As early functional priorities were met in each of the classes of systems, a second or even third level of need was identified and addressed. Before long, the developers of one class of system found themselves addressing needs that had already been solved by colleagues working with a different type of system. For example, the HIS was asked to meet clinical needs such as checking for drug-drug interactions and departmental needs such as drug tracking. At the same time, CISs were adapted to handle practice management problems such as patient billing. Through this process, it became apparent that there is virtually complete overlap between the same set of functions required by the different user populations. The only difference lies in the frequency with which a function will be used and, therefore, its perceived priority.

The networking of the late 1980s provided the opportunity of connecting these systems together electronically. Now, the demographic and admission data could be passed from the ADT system to the various departmental systems. A virtual HIS was now conceivable by using different type systems developed by different vendors. Unfortunately, in the absence of data interchange standards, such an approach was costly since all interfaces between systems had to be custom-designed. Several standards organizations were formed to create the necessary standards. Much progress has been made in this area, but much work remains [20].

## Functions of a Hospital Information System

An HIS is composed of a set of functional modules. A department uses the appropriate modules to perform a directed task and then communicates with other modules or departments. The integrated database and communication aspects are the primary differences between a departmental system and an HIS.

The major functional modules are defined below. Any given system may implement any number of then for each department.

1. *Admission/Discharge/Transfer* is the core of any hospital information system. At a minimum, this module must establish a patient record, provide a unique identification number, and document the place of encounter. Other functions include bed availability; call lists; scheduling; collection of demographic data, referral data and reason for admission; precertification; verification of benefit plan and ability to pay; preadmission orders and pre-surgery preparation procedures.
   The admission process includes update preadmit/appointment data; create the hospital account number; collect admitting diagnosis; initiate concurrent review; notify dietary, housekeeping and human services; collect/initiate orders; notification of orders/requisitions; bed assignment; notification of arrival to all interested parties; census with locators by patient name, identification number, account number, nursing station, physician group (includes primary, admitting, referring, and consultants); organize workflow by data to be reviewed, reports to be completed, and reports to be verified/signed; bed control; room charging including variable services/room and multiple patients/day; concurrent review including utilization, quality assurance and risk management; transfer of patient including bed control and discontinue orders; pending discharge, including notify next admission,

prepare discharge medications and contact home health provider; discharge, including verify diagnoses and procedures, discharge summary, patient instruction and return appointments; and case abstracting, including diagnosis/procedure coding, diagnosis-related group statistics and retrospective review.

2. *Accounts receivable management* at a minimum consists of charge capture for the transmission to another system. Other functions include charge capture with utilization review, professional and technical component billing, proration of revenue, corrections and late charges; adjustments and payments; account aging by method of payment, by category of patient and category of physician, by date of encounter, by inpatient/outpatient and by date of payment; and collections, including delinquent accounts report, collection comments, dunning letters, turnover letters and collection agency reports.
3. *Order entry* is a requirement common to almost all service departments in the hospital. At a minimum, orders may be entered in a batch mode as a method of charge capture. The full functionality includes initial order capture of procedure, urgency, frequency, scheduling (begin date and time and duration), performer, ordering physician and comments; order verification; order sets; activation of preorders; check for inappropriate orders including frequency by patient, match to diagnosis, negated by medications and credential verification; order followup including look-up patient by requisition number, list overdue pending orders and list continuing orders due to expire; initiate work, including insertion on work to be done, list by service department and nursing station, print requisition, queue for scheduling, and print labels; and enter charge if billing on order entry.
4. *Result reporting* varies markedly between departments. Minimum result reporting consists of notification that a procedure is complete. Other functions include cancel procedure; entry of result including flag process complete and bill; enter normal/abnormal range (numeric, coded or text); check data for accuracy through edit tables and internal consistency such as delta checks; and report result including immediate result reporting, flow sheets or graph, related calculated results, and physician prompts.
5. *Departmental management functions* include inventory control of supplies, drugs and perishables; item tracking of such things as specimens, charts and films; revenue and utilization statistics; word processing; electronic mail; general ledger; personnel and payroll and personnel scheduling.
6. *Specialized Functions Programs* are required to perform specialized functions for departmental service systems. Some examples are defined below.

In the *clinical laboratory*, tasks include accession numbering, collection list, specimen tracking, specimen logging, automatic capture of results from instruments, quality control, processing controls, calculation of means and standard deviation for a test, analysis of patient trend, technologist verification, check for drug/test interactions and protocols.

In *radiology*, tasks include result reporting (preliminary, final, amended results), electronic signature, reference file, and images of various types.

In the *pharmacy*, tasks include verification of order by pharmacist, dual result reporting by pharmacy (number dispense) and by nurse (number administered), unit dose tracking (fills and returns), IV admixture and chemotherapy protocols.

For the *nursing system*, the system must accommodate nursing care plans, medication administration plans, nursing diagnoses and nursing notes.

From a *medical records* perspective, the system must support a list of all diagnoses, an encounter-oriented summary, time-oriented summaries (flow sheets), utilization review and longitudinal studies.

In *dietary*, tasks include meal planning, menu selection, food distribution, inventory, ordering, nutrition management and drug/food interactions.

*Consultation programs* which should be available include bibliographic retrieval, calculations, models, decision-support systems, protocols, and medical knowledge bases such as the PDR, Emergency procedures and Poison Index.

Other general areas of concern include electronic data capture for patient monitoring and charting and such miscellaneous functions as energy control, marketing, fund raising and improved public relations.

Finally, the needs of the patient must be addressed. Patient support should include security, privacy, confidentiality for patient data, information sheets for patient education and awareness, concern for the general patient welfare, reminders of appointments, admissions, tests and health maintenance reminders.

## Systems of Today and the Needs for Tomorrow

Today's hospital information systems are primarily built around the framework of technologies and philosophies of the 1970s. As new concepts and new technology have come into being, these classical systems were modified, most usually at the surface level, to accommodate these changes. Most of these systems were designed with no thoughts of a computer-based patient record. In fact, most of these systems, even today, retain the data relating to a single hospitalization for only a few months. The orientation of these systems remains problem-focused and task-oriented. These systems use a mainframe computer, a central database and character-based terminals. Few of these systems support a unified patient problem list and complete, integrated studies and therapy data sets.

Some new systems are currently under development using today's technologies. Many of these new systems, for example Cerner, are being built around a CPR using distributed architecture. Most use client/server architecture, a graphical user interface, and a function-oriented workstation. Most of these systems still have many problems to solve before a fully-packaged, smoothly running system is commercially available.

Today's systems are primarily an automation of the manual system for health care delivery. The design mentality supports the flow of documents as the primary communication. The traditional paper chart still exists in even the most computerized hospitals of today. No major systems exist today in which all data and the management of that data is computerized.

Tomorrow's system must come from a major paradigm shift. The underlying philosophy must be patient-centered - what are the requirements of a system whose primary purpose is to provide the mechanism for the most efficient and economical care possible for humans. Rather than using the computer to improve the current paper-oriented system, the new systems must answer the question: Given this powerful computation device with massive storage and ubiquitous network linkages, with graphical interfaces, image display capabilities, vast and instant data analyses, and personalization of function, what can and should the health care information system of tomorrow provide?

First, a patient-centered record requires all data relating to the patient and the patient's well-being to be available at all times and at any appropriate location. Data from primary care physicians, specialists and hospital stays must be integrated into a single record. This record is a virtual record and may well be stored in a variety of locations. A common problem list and a complete drug list with patient allergies must be maintained and widely available. Data must be shared among all the providers of care. The patient record must be a lifetime record, extending before birth to after death.

The new HIS will contain character-based data, image data, waveforms, drawings, digital pictures, motion videos, voice and sound recordings. The networks tying these systems together must have a wide bandwidth in order to accommodate the volume of data which must be exchanged in real time among facilities. Electronic mail will provide easy linkage among the providers requesting consults and discussing a patient's care. A clinically rich common medical vocabulary whose major purpose is communication must be created and used by all participants. Confidentiality and privacy issues must be adequately supported with patient consent for the sharing of data.

The new system must support source data entry, most specifically by physicians. Most of the computer support algorithms are useful only if they are interactive with the person making the decision at the time of decision making. Workstations customized for physicians, nurses, and other clinical personnel as well as administrators and researches will be mandatory for tomorrow's systems. The move toward managed care increases the necessity for informed, algorithmic-driven order sets.

Decision support systems, operating in the background, will save much money as well as improve patient care. A typical physician session involving ordering tests and prescribing treatment may typically invoke several thousand decision rules. These decision rules need to be standardized and shared by the international community.

Much of the functionality of today's systems must be retained. The transmission of orders, processing of orders, and reporting of results still remain. Functional requirements of ADT, scheduling, department service management, supply replacement, inventory, materials management, and documentation still remain. Quality assurance should occur in real time, rather than recognizing days later that something was overlooked or that a mistake was made.

Schwartz states "that few systems have fully explored the possibility that the computer as an intellectual tool can reshape the present system of health care, fundamentally alter the role of the physician, and profoundly change the nature of medical manpower - in short, the possibility that the health-care system by the year 2000 will be basically different from what it is today [21]". We clearly have a distance to go.

## Acknowledgement

Some of the material in this paper was taken from material written earlier by Dr. William W. Stead and Dr. W. Ed. Hammond.

## References

1. Collen MF. HIS concepts, goals and objectives. Towards new hospital information systems. In: Bakker AR, Ball MJ, Scherrer JR, Willems JL, eds. *Proceedings of the IFIP-IMIA Working Conference*. Amsterdam: North-Holland Publ Comp, 1988: 3-9.
2. Feinstein AR. Cmputers in medicine: automation vs. improvement of status quo. Spring Joint Computer Conference, 1969:715-6.

3. Ball MJ. Am overview of total medical information systems. Meth Inf Med 1971;10:73.
4. Bekey GA, Schwartz MD. *Hospital Information Systems*. New York: Marcel Dekker, 1972.
5. Ball MJ. Computers: prescription for hospitals. Datamation 1975;21:50.
6. Jackson GG. Information handling costs in hospitals. Datamation 1969;15:56.
7. Hodge MH. *Medical Information Systems: A Resource for Hospitals*. Germantown, MD Aspen Systems Corporation, 1977.
8. Hodge MH. History of the TDS Medical Information System. In: Blum BI, Duncan K, eds. *A History of Medical Informatics*. New York: ACM Press, Addison-Wesley Publ Comp, 1990:328-44.
9. Hall P, Mellner C, Danielsson T. J5-A data processing system for medical information. Meth Inf Med 1967;6:1
10. Anderson J. Kings Hospital computer system (London). In: *Hospital Computer Systems*. New York: Wiley, 1974.
11. Barber B, Abbott W. *Computing and Operational Research at the London Hospital*. London: Butterworths, 1972.
12. Reichertz, P. University of Hannover Hospital computer system (Hannover). In: *Hospital Computer Systems*. New York: Wiley, 1974.
13. Abrahamsson S, Bergstrom S, Larsson K, Tillman S. Danderyd hospital computer system. II. Total regional system for care. Comp Biomedical Res 1970;3:30.
14. The DIOGENE hospital information system. Geneva: Hôpital Cantonal Universitaire de Genève, 1983.
15. Scherrer J-R, Baud RH, Hochstrasser D, Ratib O. An integrated hospital information system in Geneva. MD Comp 1990;7:357-66.
16. Bakker AR. The development of an integrated and cooperative hospital information system. Med Inf 9:135-42, 1984.
17. Warner HR. History of Medical Informatics at Utah. In: Blum BI, Duncan K, eds. *A History of Medical Informatics*. New York: ACM Press, Addison-Wesley Publ Comp, 1990:357-66.
18. Bleich HL, Slack WV. Designing a hospital information system: a comparison of interfaced and integrated systems. MD Comp 1992;9:293-303.
19. Dorenfest. History and impediments to progress in the development and implementation of the computerized patient record. In: *Proceedings of the 1993 Annual HIMSS Conference*. 1993:83-92.
20. Hammond WE. Overview of healthcare standards and understanding what they all accomplish. In: *Proceedings of the 1993 Annual HIMSS Conference*. 1993:113-24.
21. Schwartz WB. Medicine and the computer: the promise and problems of change. N Engl J Med 1970;283:1257.

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