PROPOSAL OF A HOSPITAL INFORMATION SYSTEM FOR A TEACHING HOSPITAL

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Our University Hospital is a very good example of the great complexity of the flow of information through it which becomes a road block for its smooth operation.

Starting on its random architecture, following by the multiple dependency of its personnel (Rectorate, Medical School, non paid personnel etc., the different sources of income (Rectorate, Hospitals'Union, Students funds, Insurance companies etc.) and finishing with the handling of information in different ways by diverse hospital services on patient information and care, test results etc., and the not small fact of a numerous staff: doctor residents, concurrents and students who check or treat patients.

Economical and sociological problems of modern medicine make way to a crowded Hospital; and the lack of an easy flow of information makes the system very costly in human care, time and money, interfering with its smooth operation.

A well planned (step by step) Hospital Information System (HIS) could greatly help in solving this problem. Well planned means to perfectly understand what is a HIS, its advantage, how to use them properly and its pitfalls and how to try to avoid them.

The purpose of this paper is to explain what is a HIS and how to properly prepare for it. To properly understand the concept of a HIS we shou'd know what is an Information System and a Communication System in a hospital environment.

Information systems contain individual objects related by defined relations, the actions of which are acquisition, storage extraction and representation of information. Information Systems are related to an environment, i.e., they themselves are objects (subsystems) of a larger system connected to the other objects by interfaces. Thus, a laboratory information system is a subsystem of a hospital information system.

The relations to the environment have to be defined in order to ensure a smooth comunication. The user is only interested in the interface problems addressed by this requirement, whereas the internal architecture of a computer-supported information system is of minor importante to him.

The following example demnostrates how strong decision support functions influence the design of an information system: Suppose there is a simplified version of a computer-supported system for surveillance of bed occupancy, covering the bed plan of the hospital as well as each admission and discharge of a patient. If properly developed, the system will always be able to present valid data concerning the number of free beds. However, in practice, the queries of a user become much more complex very quickly. For example, in addition to the report "10 beds free" it might be interesting to know why there are only 10 free beds. This question relates to the question of who occupies a certain bed and when a certain bed will presumably be free. Answering the last question may be quite complex and belongs to the area of decision support (is the state of a patient such that his discharge might be assumed after two days? If not, why not?).

This example illustrates a central problem of computer-supported information systems. The systems practically relevant for medicine are dynamic systems, which change their state depending on time. This dynamic aspect is also incorporated into the interfaces and the objects of the environment (information transmission to the outside world depends, for example, on the availability of the receiver).

The additional influences have to be distinguished from these temporal changes:

- Information requirements of the outside world changes in reaction to a computer-supported information system. Even a most careful systems analysis cannot prevent some information, initially classified as essential, to change to never needed, or new specifications or requirements emerging soon after putting a system into operation.
- Natural development of the outside world results in new information and in new information requirements, for example, by developing new tests with new and so far unknown diagnostic possibilities.

Communication System

Basic to an information system is the transmission of messages. Therefore, information system rests on a communication system comprising individual stations and connecting communication lines. A station may be a transmitter, a receiver, and/or an exchanger of messages.

A communication line can be dedicated, i.e., strictly assigned to a transmitter and a receiver, and it can be used in a direction or in both directions. In addition, there are general communication lines used by more than one transmitter and/or receiver.

The architecture of a communication system rests on its functions for message transmission; in addition, it depends particularly on its sensitivity to the failure of individual components, on its extensibility by new components, and on its costs (Fig. 1) [3].

Each station in a ring is connected to two neighbors. The ring is relatively simple and easy to extend, but it is sensitive to the interruption of a connection. This is particularly true, when messages are only transmitted in a single direction.

This disadvantage is not present in the complete ring, which, however, has high costs for extensions. Extension by an additional station requires establishing all connections to each one of the stations already present.

The bus is a general communication line, whereby the source must obtain "control" of the line prior to message transmission. If the bus is interrupted, then all connections are interrupted.

The star has a central exchanger. It is relatively simple and easily extendible. If the exchanger fails, then all connections fail.

In the regular net each station is also exchanger and decides to whom an incoming message is to be transmitted. In general, the regular net combines the characteristics both of the complete ring and the star.

Complex communication systems may be hierarchically structured. A frequently used principle is the local concentrator, which takes over the communications with other subsystems (Fig. 1).

Hospital Information System (HIS)

At present, the definition of information systems is so general that the individual functions of a HIS are not specified. Therefore, very different systems are described in the literature, which are called HIS.

A first structure is derived from the structure of a hospital:

Patient care: wards, ambulatory units

Functional unit: laboratories, radiology, nuclear medicine, ECG-unit,...

Supply: pharmacy, blood bank, technical stock, kitchen.

Administration: admission, accounting, billing,.

These four areas are completed by research and teaching in university hospitals.

Objectives of a Hospital Information System [5]

Patient data are the source of all activities in a hospital. Because data captured at a certain station are needed by other stations in order to do their tasks, data acquisition, input, storage, retrieval and transmission must be organized.

The most important objectives of a HIS are:

a) improvement of information, b) acceleration of presentation of information, c) rationalization of course of operations, d) relief from routine work, e) decision support.

Improvement of information can be obtained in several ways. Reducing the frequency of data acquisition - in the optimal case each datum is acquired only once - reduces the frequency of errors. Information extraction by aggregating data from different sources improves the potential for analysis.

A typical example is the presentation of important information from patient history, already triggered by admission ("risks" such as allergies or continuous therapies).

The complete ring or the net approach the traditional hospital structure best. They are favored by the direct connection of individual stations, because the risk of communication disturbances increases with the number of exchangers. A further advantage is the fact that discounting a communication line concerns only the stations directly involved, whereas all other lines may still work. These are important considerations to be kept in mind when the fascinating advantages of a star are considered.

In a star the data are nearly all centralized and can be integrated in an optimal way. Multiple storage of data can be eliminated, whereas in a complete ring data must be stored in each node, because each station must have access to a subset of the master data in order to relate the data to the patient. This results in serious problems, especially concerning data update.

For example, if after termination of the admission procedure it appears that the name has to be corrected, then in a complete ring the correcting station must ensure that each false copy is corrected in each station storing this datum. This problem has not yet been solved with justifiable expenses and sufficient safety for large systems such as are needed in hospitals. In contrast to this, a single correction in the central data base suffices in a star in order to present the correct datum to each station.

The optimal architecture will be hierarchic. Each station must make available certain "local" data, which are also of interest to other stations. Therefore, the compromise between local independence with regard to data acquisition, update, and retrieval, on the one hand, and dependence on other stations or on a central data base, on the other hand, determines the architecture of a system in practice.

Functions of a Hospital Information System

At present, there is no HIS meeting the above-described objective sufficiently well. But subsystems have been developed and have demonstrated potential fundamental solutions of the problems. The most important functions are: 1— patient admission, bed occupancy, appointment scheduling; 2— acquisition of service requests and presentation of planning foundations for the service units; 3— service acquisition accounting and billing; 4— inventory systems; 5— menu-planning; 6— result acquisition and evaluation (clinical laboratory, nuclear medicine, ECG,...); 7— automated medical reporting; 8— documentation and archive administration; 9– decision support; 10– administrative functions (accounting, property management, financial accounts,...).

This list omits functions referred to as research and teaching. These should be conceptually separated from a HIS, even if they utilize data of the hospital organization (e.g. teaching programs utilizing "actual" data). If all computer applications in a hospital are interpreted as components of a HIS, then finally the publication of nacional statistics belongs to a HIS. But then the concept becomes so vague that it no longer means anything.

The multiple relations and the several possible realizations are explained by means of an example (Fig. 2).

Drug therapy as a component of a computer-supported HIS can be interpreted as purely a documentation problem, where for each patient all therapies are stored for later statistical evaluation. When therapy is relevant for accounting, there is an additional relation to administration, to which the therapy (including price) has to be transmitted. Because knowledge of the therapy may be relevant for the evaluation of findings, this informations is additionally made available to selected service units. Thus, evaluation of an ECG (cardiac drugs) or of laboratory results, detection of micro-organisms and their sensitivities in microbiology (antibiotics), and planning of operations (anticoagulants) depend on the knowledge of the therapy. A reliable organization of drug administration on the wards is supported by work lists (patient, time, drug, dosage) [3].

The system could be required to check the plausibility of prescriptions (invalid dosage), to offer cheaper alternatives for expensive drugs, and to indicate possible interactions (inhibition, cumulation, incompatibility) to the attending physician. There are additional relations to a drug stock on the wards, to an inventory system in the pharmacy, etc. For certain therapies the patient has to be educated. Therefore, there are relations to teaching programs for patients.

Thus, the functions related to the data concerning drug therapy may become arbitrarily voluminous and complex. Fig 2 illustrates how precisely these functions have to be specified before a computer-supported HIS is developed.

The central component of a HIS is the data base. It is updated by data input via interfaces. The structure depends on type and number of observed attributes and, in particular, on the permitted access paths. But these paths usually differ in data input and retrieval. While data input is almost always patient-oriented, retrieval has different structuring criteria such as time, location, specialty, source, method of data capture, or attribute values.

Therefore, a HIS has intimate relations to documentation systems. The mixture of objectives of a HIS and a documentation system is the most frequent cause of misplanning and failure.

Drug-Control Systems

A drug-control system is an important subsystem of a HIS. Acquisition of drug prescriptions can support decision making under different aspects, like checking of indication, dosage, and application form, or warning of drug interactions. Worksheets may be printed to support patient care including patient, time, and medication. Acquisition of drug administration affects nearly all areas of a hospital [2], as shows Fig. 3.

Several applications have demonstrated that such systems have cost-reducing side-effects, which can only be partially derived from the optimization of stock-keeping. A large part is the result of optimizing physician behavior. Many hospitals have already established a drug committee. A drug-control system practically enforces such a committee. The very first effect is the reduction of the drug spectrum kept in stock. As it happens, many drugs are in stock only because individual physicians believe that these drugs are especially effective or do not know about an alternative. Sometimes, these physicians have already left the hospital but the dormant stock remained. Indication list containing only those drugs whose effects are known and which are the cheapest alternatives reduce the costs significantly. Nevertheless, justifiable deviations from the lists may be permitted.

Peculiarities and Pitfalls of a HIS

— The conventional system has emerged over a long period and has resulted in an organizational and personal structure, which is anything but reliable even under conventional conditions.

— There are psychologic and sociologic problems of medical and paramedical personnel, which can only be solved by education and "acclimatization".

— Personnel is frequently under a stress, sometimes being so strong, that disturbances are not tolerated, especially when caused by technical devices.

— There are many exceptional cases where for most components completeness of data cannot be a prerequisite for operation.

— Precise authorization with respect to organizational decisions is missing or unproperly distributed.

— Complexity of problems and lack of experience lead to long developmental periods and unreliable hardware and software.

— All-hearted decisions require development without adequate resources in equipment and personnel (requirement for "transportable" solutions in an immature state; development of systems for routine use on computer systems, which are primarily available for research and teaching).

The "HELP" HIS

One of the foremost examples of this integrated approach to patient care is HELP (standing for Health Evaluation through Logical Processes), a system which started development in 1972 [4] under a team headed by Dr. Homer Warner, at the Latter-Day Saints Hospital in Salt Lake City, U.S.A., and now provides a 550-bed tertiary care hospital with the following repertoire of information sources:

1. Patient record (demographies, abstract of past medical history, and complete data from current admission, including all investigations).
2. Decision-making support (both statistical and rule-based).
3. Administrative (admissions, transfers, discharges, and billing).
4. Research (databases, storage, analysis, etc.).

Like the University of Pittsburgh's INTERNIST-I expert system for internal medicine, HELP is another representative of the multi-person years project philosophy. However, HELP gains a major advantage over its Pittsburgh counterpart in its day-to-day connection with clinical reality. Aside from holding a database for all of the hospital's current in- and out-patients. HELP also includes a vast knowledge base comprising "one million patient histories and 3,000 medical decision rules", which together serve to fuel the "40,000 decisions made daily" by HELP's expert system core in the area of interpretations, alerts, and therapeutic suggestions. This is achieved with a complex line-up of equipmment, including 6 mini-computers, 1,500 Mbytes of storage, 250 terminals, 70 printers and 18 microprocessor units.

But the design of HELP goes much deeper. Because HELP is the information-gathering center of the hospital, and therefore built into the structure of the hospital along with the essential services, it is able to tap into data as it becomes available from patients undergoing monitoring (ECGs, arterial gases, and blood pressure, for instance) or lab investigations, rather than relying on doctors or nurses to key in data. In fact, as HELP stands at present, it is able to assimilate and process data from all the following areas of hospital medicine: history-taking and physical examination, hematology, biochemistry, radiology, ECG, blood gases, lung function tests, haemo-dynamic and cardiac function tests, and drug therapy (including drug contra-indications). In addition to that impressive list of information storage activities, there is also a continuous monitoring facility which registers changes in a patient's condition. This is demostrated bp the pharmacy module, which alerts staff to drug allergies and sensitivities, drug interactions, inappropiate dosages and incorrect frequency of administration. In any one month, it is claimed that the module picks up an alert in 5% of patients, and a life-threatening situation in a further 1.8%. This degree of vigilance would clearly be impossible if it was not for HELP's openloop system of therapeutic guidance.

As may be seen in Fig. 4, the "cadiac" HIS is another example of a HIS.

As we see, a HIS should be not only of great value but indispensable in a modern teaching hospital. As technology improves and prices are greatly reduced, cost will not be the main barrier for its use. The real difficulty will lay in the lack of computer knowledge by the key hospital personnel.

Of course this problem can be solved by a clear policy of early teaching of basic informatics to all hospital personnel directly and indirectly involved in patient care to be able to have, at the right time, a critical number of people who not only is technically able, but is also psychologically prepared to understand that a HIS is not a system that imposes itself on humans, but is there merely to assist them.

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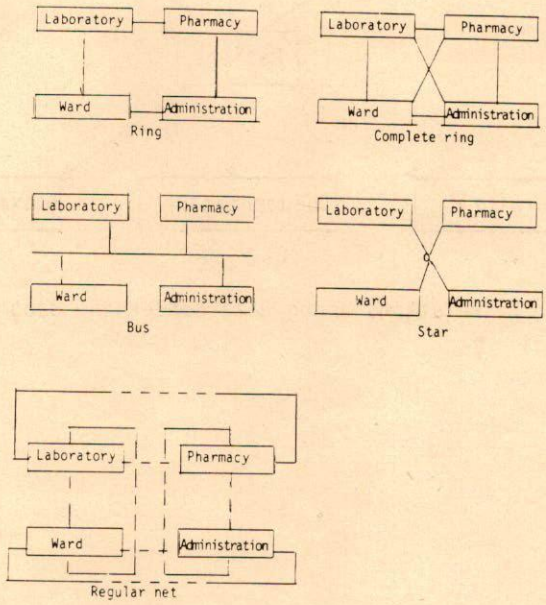

Five models of a communication system with four stations

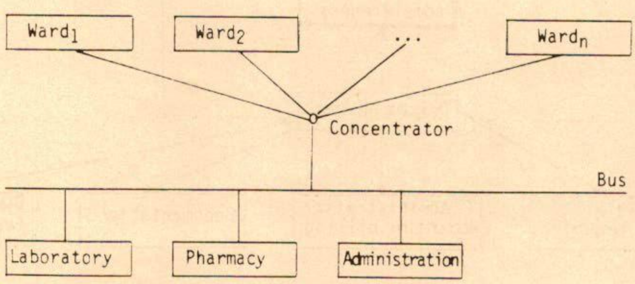

Fig. 1: Hierarchic communication system with a local concentrator and a bus.

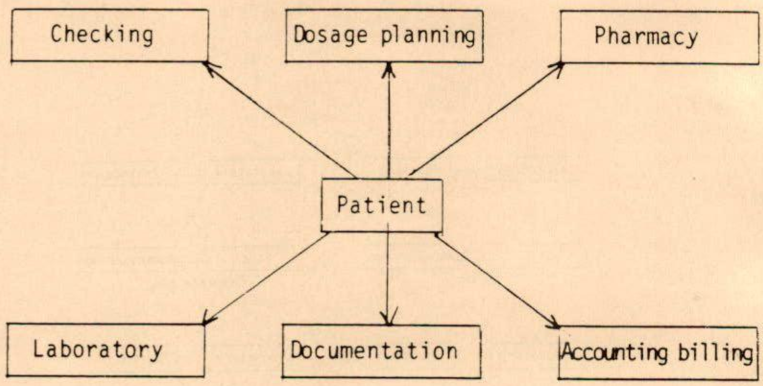

Fig. 2: Relations among data concerning drug therapy.

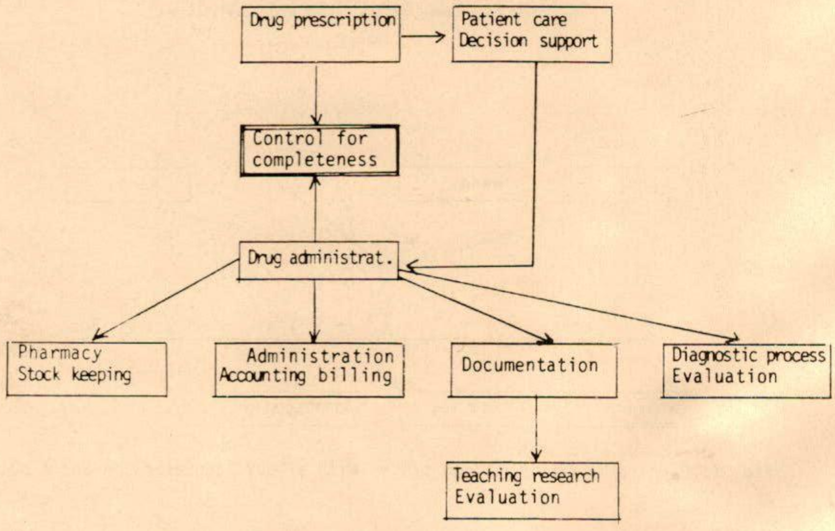

Fig. 3: Relations of a drug-control system

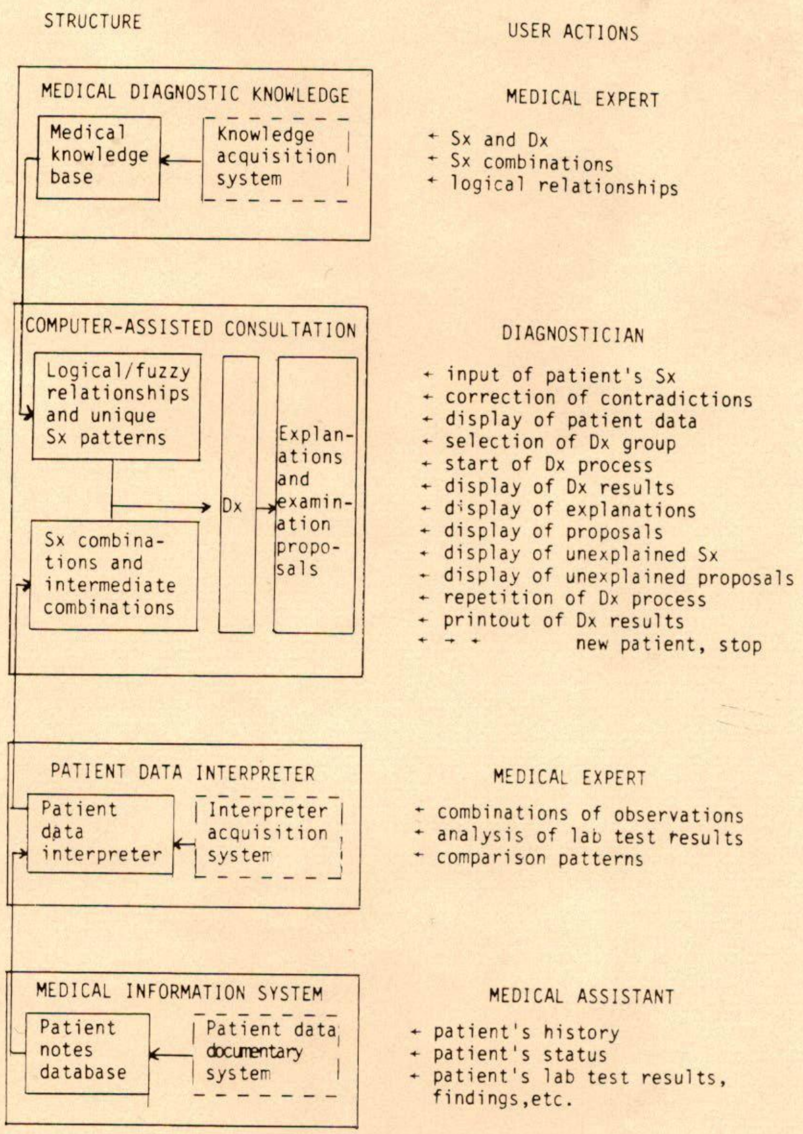

Figure 4: Block diagram of the CADIAC integrated information system. From Adlassnig K-P. et al.