MEDICAL INFORMATION SYSTEMS

Medical information systems (MIS) support and enable the diagnosis, therapy, monitoring, and management of patients and also the management of health care organizations and their resources delivering care to patients. Medical information systems are used in the same way as information systems in business and manufacturing. They support and automate certain tasks. They provide new ways to carry out patient care. In business, information technology is a strategic tool in improving competitiveness. Similarly, in health care it could empower the actors (clients/patients, care providers, and those paying for and organizing care delivery) to achieve "more health with less cost."

In the United States the application of information technology (IT) to health care started with the need to manage patient admissions, discharges, and transfers (ADT) in order to bill the financiers for the care provided to each patient. In European countries, health systems generally have a different incentive scheme with mostly publicly funded health systems. Consequently, costing and billing were not initially the focus. Instead IT migrated into health care through the different departments that benefited from IT. Microelectronics and digitization revolutionized medical devices. Devices today are embedded computers supporting such applications as computed tomography and magnetic resonance imaging. Picture archiving and communication systems (PACS) grew as a solution to the need to integrate the process of imaging and image interpretation. The same was seen in all technology-intensive domains of health care, such as intensive care, operating rooms, and clinical laboratories. Laboratory medicine was the first to utilize IT, both to automate its processes and to create new improved services to the departments requesting its services.

These opposite approaches have been merging for many years, and currently these interests are highly integrated. At the same time, the role of IT, and of information systems, in particular, has changed. The importance of information (and knowledge) to health care organizations is recognized. Today many health care organizations employ a chief information officer (CIO) and have created and maintained an information management (IM) strategy. The IM concept has evolved to cover the management of data, information, and processes across the enterprise, including the management of the IT and IS infrastructure. Although this trend is clear, its implementations in the United States and Europe are vastly different (at least for the time being). In the United States, health care organizations' investments in IT are on the order of 3% to 4% of operating costs, whereas in the European countries the figure is only about half that (between 1% and 2%).

Also, the medical information systems industry has undergone major changes. The current thinking of IT as a business enabler, through integration of relevant information and knowledge combined with new, improved services, is supported by the availability of distributed heterogeneous computing environments. These make it possible to network departments and health care organizations onto platforms sharing patient data across a continuum of care. These platforms integrate care institutions and extend to the homes of individuals, and through mobile communication anyone can be connected. This trend requires standards of interoperability and common languages, encyclopedias, and nomenclatures, to share patient and other data in context.

A myriad of medical information systems exist today, from home-grown local applications to off-the-shelf software products. The user has a choice in selecting which product to use. The range of choice is also a drawback in that the market is often nationally or regionally organized, with the result that there are too many competing solutions with a limited installation base. Vendors therefore do not generate enough revenue to maintain and update their products, much less invest in R&D for a new generation solutions. In such highly fragmented markets there is little incentive to push for standard solutions. Consequently, the user has to be well informed to understand all the options and consequences in selecting products.

FRAME OF REFERENCE FOR MIS

Medical Domains and Architectures

A greatly simplified model describing the role of medical information systems in health care service delivery is given in Fig. 1. It divides a health care unit into three parts: one containing the mission, vision, strategies, and goals of the organization; one comprising the operational system of processes, resources, and knowledge; and one with the information systems supporting and enabling operations and achievement of goals. The model illustrates two important concepts. First, it emphasizes that any health care organization must have an explicit strategy on how it intends to meet its goals and fulfill its mission. Second, the strategy must also cover the ways that IT and information systems can be used to further the purposes of the organization.

An organization can also be represented as an architecture. Architectural views differ depending on the way activities are organized and managed. One way to organize them is according to the hierarchical view of departments and clinical units. Another way to represent a health care organization is to present it as service lines supported by service units (e.g., clinical laboratories, operating theaters, imaging services, etc.) and ancillary support services. This latter process view also fits well with several current paradigms, like evidence-based medicine and clinical protocols (guidelines). In either case, an organizational architecture implies an IS architecture that complies with the needs of the operational system.

The health care domain can best be characterized as *federated*. Federation means that parties have negotiated the extent to which they wish to share common resources and thus surrender their exclusive authority over those resources. The alternatives to federation are, at the one extreme, complete

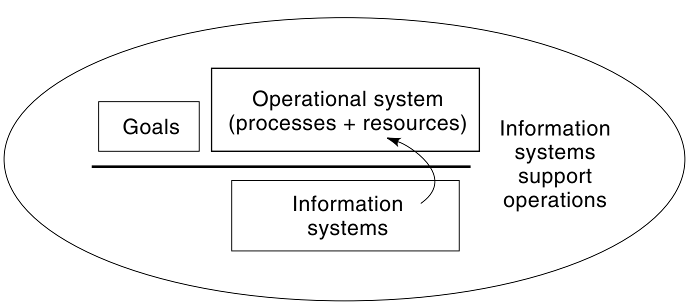

Figure 1. Simplified model of a health care organization.

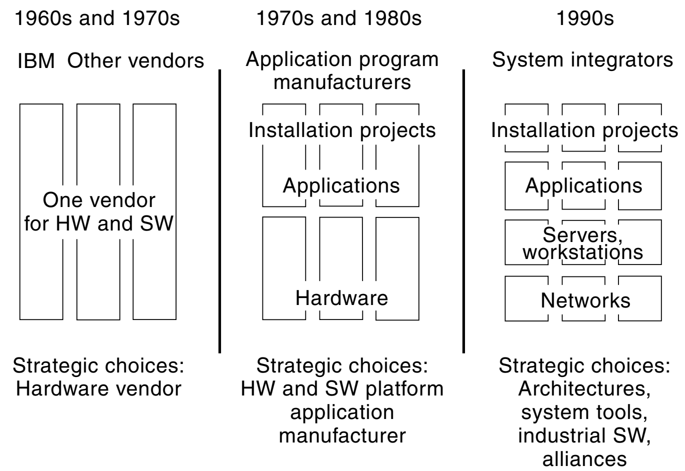

Figure 2. The strategic choices that users have to make have increased in number and complexity.

independence with no common agreements, and, at the other, *unification,* where the parties are governed by one supreme authority. In health care unification is, if not impossible, at least a very difficult and tedious task to achieve. Similarly, isolated IS islands are not any more practical. The concept of federation is an accurate description of current health care systems. Units act independently, but cooperate in patient care by sharing patient data according to mutual interests and agreements.

Consequently, the information systems supporting and enabling operations need not be fully integrated. It is enough if their domains overlap on those areas where data need to be shared. Overlapping of domains means that the organization in question jointly agrees on this. It also means that they agree to use common terminology and classifications in the overlapping domain and that they furthermore agree on a common communications protocol to exchange data. Federation is actually the solution to the dilemma that resulted from the database-centered approach of the 1980s.

At that time, integration was achieved by a common database. As the number of users and needs grew it became gradually impossible to maintain and upgrade such large monolithic systems. Hence industry was forced to find new solutions (Fig. 2). The notion of heterogeneous, federated domains emerged as a way to manage the complexity and to migrate toward meeting the needs of the enterprises. IT vendors have established consortia to develop standards to cope with this, for example, International Standardization Organization/Open Distributed Processing (ISO/ODP), Advanced Networked Systems Architecture (ANSA), and Object Management Group (OMG) (1–3). Distributed client-servers and middleware describe the current approaches.

Current mainstream IT architectures subscribe to the federation principle. Consequently, ISs are otherwise independent, except that they have interfaces through which they communicate with other IS applications. This also means that health care organizations can use different information systems to support different operations, with the provision that these can communicate in their mutual federated domain. This gives users the freedom to select "best-in-class" applications, but at the same time requires that attention is paid to

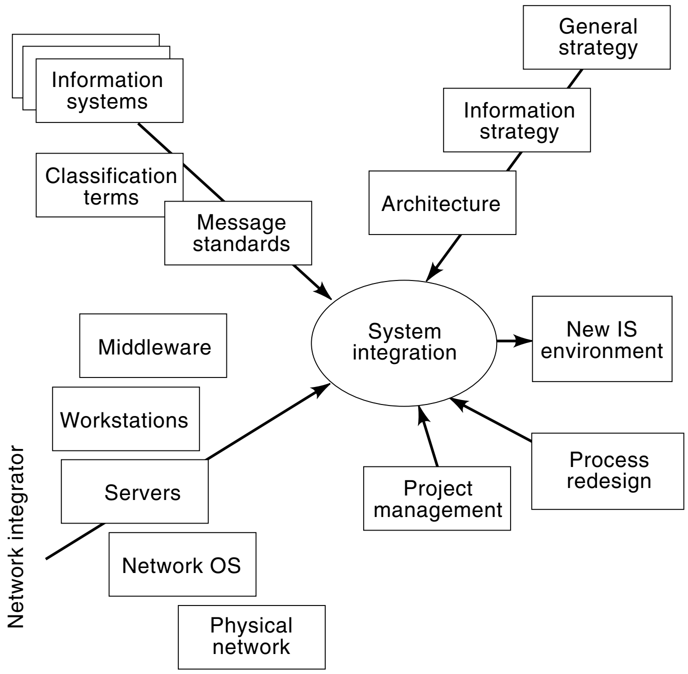

Figure 3. System integration comprises process and IT integration and requires strong abilities in people and project management.

the interconnection of these systems. *Interoperability* means that ISs can communicate among themselves using standard messages and protocols.

The drawback to this is that users today face a much more complex environment than in the past. Whereas in the early days it was enough to select a vendor for the hardware, today the user needs to make an educated choice on a number of issues, such as what IS architecture to have, what software tools to use, what applications to select, and finally with whom to manage and develop this infrastructure (Fig. 2).

Systems integration is the function where information systems are made to work together in their federated domain (Fig. 3). Systems integration comprises, in addition to the technical integration of information systems, the redesign or streamlining of the care processes supported and enabled by these ISs. It also means that a systems integrator must be highly competent in people and project management.

IT—An Agent of Change

As in business and manufacturing industries, health care uses information technology as a strategic change agent to improve efficiency, quality, and effectiveness, and to contain cost. This idea is based on the unique enabling capabilities of IT to provide new ways to diagnose, treat, and monitor patients, and to allow patients to take a more active role in this process (Fig. 4). IT is a vehicle that empowers all actors (citizens, patients, clinical staff, management, third parties, health policy makers, etc.). However, there are no "cookbook" recipes on how to do this. If there were, the health systems of different nations would be similar. As it is, today most countries have recognized the need to reform their respective health care systems. Although certain similarities exist overall, countries have selected different methods and tools to do it. This also highlights the highly heterogeneous nature of health care and underlines the need to model it as a federated domain. Although there are no recipes on how to do this, the first benefit that medical information systems have provided is the ability to make better decisions: Physicians have an integrated view of all data relating to a patient and can combine this with current medical knowledge to arrive at diagnostic and therapeutic decisions or to reevaluate current therapy and diagnosis. Similarly, aggregation of patient resource use and cost data allows managers at all levels to evaluate current practices and to design new ones.

Information Management

Information management (IM) facilitates the business mission of the enterprise by managing its information, processes, and technology (4). An illustration of what IM contains in the case of health care is given in Table 1. IM is not concerned with the management of data and technology only—processes are also included. Information management has a broad focus in seeking ways to improve the functioning of the enterprise in question. Consequently, the role of information technology

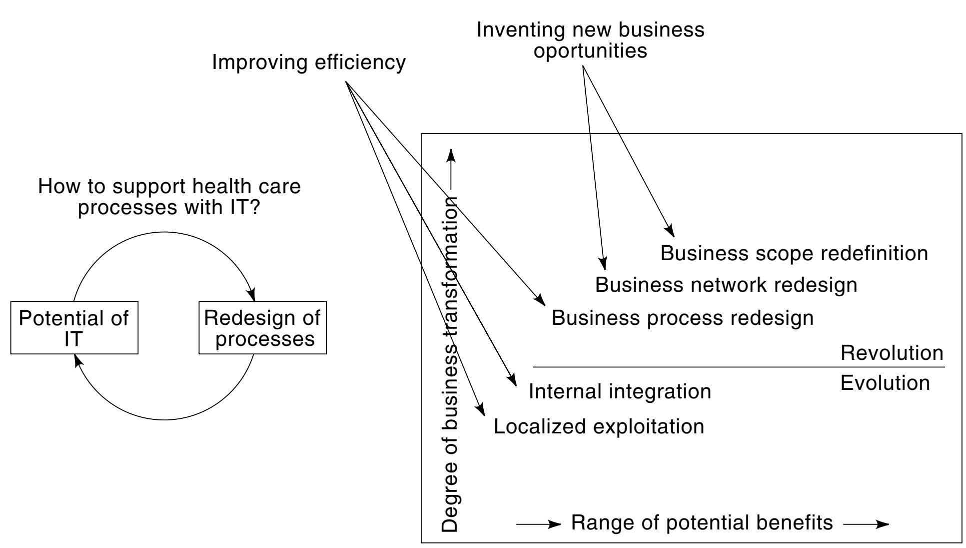

Figure 4. IT enables the creation of new information system products that, in turn, support and enable new ways for providing care to patients.

Table 1. What Information Management Is and Is Not

Is . . .	Is Not . . .
Application of management principles to information	Automation of existing processes
Whole enterprise	Department
Data, process, and technology	Just systems or computers
Resource approach	Technically driven
Information stewardship	Just data management
Management of a critical resource	Isolated islands of data
Business enabler and driver for systems and technology deployment	
All forms of information	

is changing. Whereas in the past it was seen as an expense, it is now an investment (Table 2). This entails the notion that IT costs can be recovered as benefits in improved efficiency, quality, or effectiveness, or in reduced operational costs. A further corollary of this is that the IT leader, or chief information officer, is charged with making this all happen (Table 3). To succeed, the CIO must be a tactical planner, systems integrator, collaborator, change agent, and customer advocate.

MIS Standards

Standardization in MIS is composed of two issues: The first deals with medical practice and medical data; the second, the exchange of medical data among MIS applications. In the heterogeneous changing environment of health care, standards are greatly needed. However, due to its complexity, standards are difficult to establish. This is seen on all levels of activity. The medical profession is concerned with effective and efficient care. In the standardization context this has resulted in a number of classifications and nomenclatures spanning the whole medical domain [e.g., International Classification of Diseases (ICD-10) and Systematized Nomenclature of Human and Veterinary Medicine (SNOMED) (5,6)] and specialized domains (e.g., primary care). In recent years the need for evidence-based medicine has been increasingly recognized (7). This is partly due to the efforts in formalizing care through care protocols, also called clinical pathways and clinical protocols. The results of these activities have been disappointingly slow. This has led to the realization that local care practices need to differ mostly for two reasons. First, the local circumstances need to be respected, as well as local demographics and epidemiology. Second, as medicine is partly an art and

Table 2. Role of Information Technology Has Changed from an Expense to an Investment Approach

From an Expense . . .	To Investment . . .
Small sums of money	Large sums of money
Operational view of benefits	Strategic view of benefits
Must we spend this?	We must spend this!
Discontinuous and discrete spending	Continuous investing
Cost analysis	Investment appraisal
Self-financing by cost savings in other areas	Capital planning
Cost management	Benefits management
Expense accounting	Asset accounting

Table 3. IT Leader's Duties

Tactical planner	IT plans must align with the organization's strategies and objectives
System integrator	Initiate and develop an IT plan that facilitates the organization's objectives and has the flexibility to adjust as "marketplace" changes. Optimizing the ground between "best-of-breed" and "one system" extremes
Collaborator	Integration of people and cultures. Using IT to break down interdepartmental, interdisciplinary and interorganizational barriers
Change agent	Facilitator and "perpetrator" for collaboration. Success of quality improvement initiatives depends on the capture of data.
Customer advocate	Meeting both internal and external customer requirements. Being responsive, timely, flexible, and open to improvement

partly hard science, there is not enough evidence to warrant standardizing care practices across all medical problems.

Countries have initiated health reforms in order to deliver more and better quality health care with fewer resources, that is, cost. Thus care management has become one of the priorities. Means and indicators are needed to measure what resources are needed and what outcomes are produced. Diagnostic related groups (DRGs) have, since their introduction, been applied in many forms across health care systems (8). Managed care and disease management are recent concepts with the same goal.

The heterogeneity of the clinical domain affects medical information systems and ways to integrate them into an interoperable infrastructure. The basic notion is federation, that is, do not try to agree on everything. It is enough to agree on what data and context need to be shared. Communication takes place with messages. Open systems is also a buzzword in health care. Although quite a lot of energy has been invested in international standardization efforts in this area, there is not much to show for it. Instead de facto standards developed by user groups and industries dominate. Health Level 7 (HL7) is the most notable example of data exchange (9), together with Digital Imaging and Communications in Medicine (DICOM) (10). Both have also gained wide acceptance outside United States and are well supported by vendors of medical information systems and imaging modalities and networks. The success of these comes from two factors. First, both allow a certain degree of freedom in implementation (which also means that implementations are not necessarily compatible). Second, both rely on integration engines (message brokers) as the hub receiving and sending messages, thus reducing the number of connections needed between medical information systems in a complex environment. Additionally, some domain specific standards exist, for instance, for exchanging laboratory orders and results (11).

Edifact is the third category of message standards that is being used widely. Whereas HL7 and DICOM are meant mainly for messaging between component systems of a health care organization, Edifact is intended to be used in asynchronous messaging between organizations (12). In Europe several Edifact-based prestandards have been produced by the Health Informatics committee of CEN, for example, for laboratories and drug prescriptions (13).

Middleware is a product of recent years. It is the result of a migration from both the applications and physical layers of services that are common across different environments. Its need has emerged with the three-tier architectures of distributed client-servers and object orientation. A number of international consortia are competing in developing these common services for health care. The main contenders are CORBAmed and Microsoft, and in Europe project consortia STAR and HANSA (14–17). However, these are ongoing activities whose outcomes are still uncertain. For users who need to decide today, the only practical solution are the message brokers based on HL7 and DICOM.

Today the network infrastructure can combine a number of technologies from the TCP/IP based Local Area Network (LAN) and Ethernet to Integrated Services Digital Network (ISDN) and Asynchronous Transfer Mode (ATM) switches. In addition to copper and fiber-optic cabling, connections can also be provided by mobile networks. Consequently bandwidth, as such, is no longer a limiting factor.

As shown above, standardization efforts in the health care domain can be divided into two broad categories: de jure and de facto (industrial) standards. In the former category the work has only begun. The slow progress is due to the nature of medicine. It is evolving at a rapid pace and at the same time a substantial part of it is based on experience rather than hard evidence. This is also the reason why industry standards such as HL7 and DICOM have been so successful. It is also the reason why federation is today the only feasible approach in the creation of an integrated information system infrastructure for a health care enterprise. For middleware and physical infrastructure there are no good reasons why health care needs its own special solutions. Instead health care should use mainstream technologies. This way, health care can leverage the progress and price/performance ratios in mainstream products rather than having to rely on niche vendors specializing in health care.

Frame of Reference

The following are a few suggestions for users to stay competitive and survive in this changing environment:

- Create an information management strategy supporting and aligned with the goals of the health care organization.
- Create an open architecture for the MIS, based on mainstream IT products, system integration, integration engines, HL7, and DICOM.
- Create a plan to migrate from the current ad hoc (possibly monolithic) environment to this open architecture.
- Buy best-of-breed medical information systems and use the architecture and open interfaces to create the necessary interoperability between system components.
- Use IT projects to trigger change in health care processes and in the organization.

STATE-OF-THE-ART IN MIS

A complete description of available medical information systems is beyond the scope of this article. Also, such lists are outdated as soon as they are done. Instead, a generic approach is attempted, where the question of MIS is approached from the medical domain dimension of the health care information framework, that is, what is the medical domain supported by the application, and what capability is included?

The basic task in health care is patient management. This comprises three activities: diagnosis, therapy, and monitoring. The complexity of the task depends on the individual case. The patient may have a problem that can be treated with a single visit (or contact). Or the problem may require referrals to other specialists and care units leading to multiple visits. These extremes illustrate the problem of providing effective, high-quality care efficiently at an acceptable cost to citizens. A wide range of medical information systems has been developed over the years to support patient care and management. As the emphasis in health care has shifted, the MIS have evolved.

The current care environment can be captured in the following phrases: patient-centered, process oriented, clinical guidelines, evidence-based medicine, electronic patient record, management information systems (including case management), structured data (including nomenclatures and encyclopedias), general practitioner/gate keeper, regional seamless care delivery, citizen-centered care and health promotion, telemedicine and the Internet, data confidentiality and data security, and solutions for independent living and security. The following provides a description and discussion of these phrases.

Patient-Centered and Process Oriented

There are at least two ways to look at a health care enterprise: organizational and process oriented. Until recently, hospitals were managed by dividing them into organizational units, like admission/discharge/billing, policlinics, wards, care service units (especially radiology and laboratory), operating rooms, and so forth. As medical information systems are intended to support the organization, the kind of MIS applications that resulted were in accordance with the above organizational structure. Management of the hospital was done through these units, leading to a situation where each unit is optimizing its performance at the cost of others. The job of the clinicians treating patients is to coordinate these in the best interest of the patients. At the same time hospital management is faced with the need to be cost-effective and to contain costs without compromising care.

As these demands are conflicting and cannot easily be reconciled in such an organizational structure, process orientation is winning ground. It has been pioneered with great success in business and industry. Total quality management (TQM), continuous quality improvement (CQI), just-in-time (JIT) delivery, flexible manufacturing, logistics, and others tell of the different facets of the process approach.

A note of warning: Although care processes should be preplanned, they cannot be completely rigid. Each care process is unique. The needs of the patient and the means of the health care unit determine what can and will be done. Furthermore, plans may need to be changed as new evidence emerges.

In health care, solving the problem of a patient can be seen as a process: a chain of partly sequential and partly parallel diagnostic and therapeutic actions. The challenge is to manage these events in order to optimize the outcome and the use

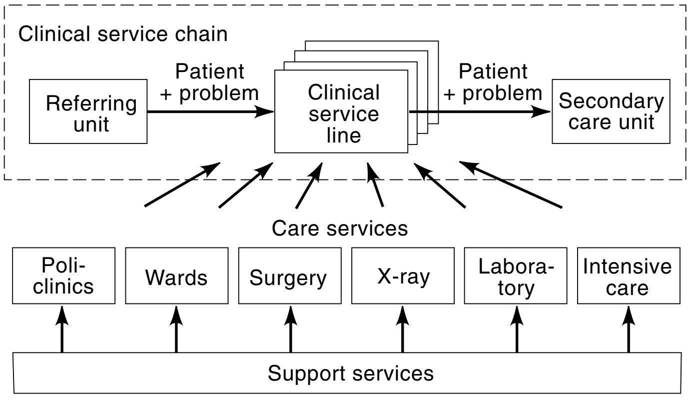

Figure 5. Process-oriented organization of health care delivery.

of resources needed during that process. The process paradigm leads to a new organizational structure for care delivery (Fig. 5). Resources are reorganized to serve the main activity of problem-solving. The core activity is the clinical service line, which uses the skills of service units such as laboratory, radiology, surgery, and wards, according to need.

In the organization unit structure MISs support different units, including laboratories, radiology, picture archiving and communication, pharmacy, intensive care, anesthesia and operating rooms, administration, blood-banking, kitchen, maintenance, cleaning, clinical engineering, and so forth.

This creates a need for a "glue" that integrates the patient data created in the different units and makes it available where and when needed. This is supplied by the application program interface (API) and the message brokering technology utilizing message standards, such as HL7 and DICOM. The patient data store is the electronic patient record. Systems integration is the function where these MIS applications are "glued" together into an interoperable environment.

The resulting MIS architecture has no "order." All applications are equal. This equality has created a further need. The clinicians need to have an overview of what is happening with the patient, that is, how the care plan that they devised is being implemented and with what success. Therefore applications like "clinician's workstation" have been created to provide an integrated picture of the care process. In fact, although the organization is a top-down structure, care is administered in processes.

In the process paradigm, the MIS architecture centers on service. The clinician responsible for a patient designs a care plan. The care plan may contain orders for tests and procedures that are delivered by the care service units. The care plan is reviewed at regular intervals and when new data become available it is adjusted/redesigned according to need. The MIS paradigm for this approach is called "order/entry" (O/E). O/E systems have lately been highly successful, as they provide a way for the clinician to be in control of the procedures performed on the patient and/or on samples taken from the patient.

Common Services

As the understanding of care delivery and of ways to support it with information technology has matured, the need for an infrastructure architecture has emerged. An architecture defines what the total system is, what function it provides, and how the pieces that make up the whole system interact. Integration with message brokering is an architecture. Some MIS applications are used by all, whereas some serve only one function. In other words, there are common and specific services provided by MIS applications. Additionally, there are services that are even more common and that are needed in all IT environments, independent of whether or not that environment has a medical purpose.

Identifying these common and health-care specific common services is attempted by a number of consortia made up of industry and user organizations. The Object Management Group (OMG) is defining a common object request broker architecture (CORBA) and is in the process of identifying these common services (3). As a part of that activity, a health care specific task force has been established with the name CORBAmed (14). Microsoft's OLE/COM and its Healthcare Users Group (HUG) compete with OMG, although some agreements exist on how these can coexist (15). A third approach, known as the Andover Group, combines the strengths of both, building on HL7 (18). HL7 itself may be also a contender as it is moved toward full object orientation (9). In the European context, a prestandard on health-care specific common services exists. It has been produced by the medical informatics committee (TC 251) of the European Standardization Committee (13). The health care common components (HCC) identified are: patient, health datum, activity, resource, authorization and concept (19). The roots of this activity are in a stream of European Union-funded projects that started nearly 10 years ago (16).

Another prestandard by TC 251 presents a health care information framework (HIF) that can be used to view any health care organization and the MIS it uses (20). The HIF comprises three views: (1) health care domain, (2) technology, and (3) performance requirements (Fig. 6). All MIS environments must have the required functions—be dependable and controllable. These requirements are met by technology in three layers. Where they are located depends on the solution. For instance, data privacy and protection can be an integrated feature of an MIS application, or there can be a common middleware service for this across all MIS applications. The management of data privacy and protection in a MIS environment is certainly going to be easier if that function is located in the middleware layer than if changes and updates require manipulation of all MIS applications.

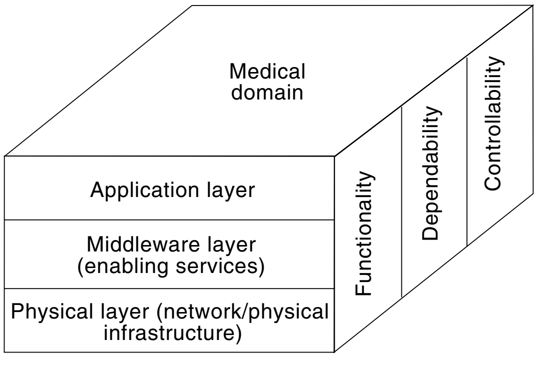

Figure 6. Health care information framework of three views.

Clinical Guidelines and Structuring of Data

The process approach of organizing care into procedures ordered to be performed leads to protocol-based care. The activities needed in handling the problem of a patient can be seen as an instantiation of a template containing that "care package." Clinical protocols are used routinely in clinical research to determine the efficacy and effectiveness of, for example, new drugs and medical procedures. They are also commonly used in cancer therapy and in other medical specialities.

As each patient is an individual, protocols cannot be applied in every detail. Instead, the user must have the freedom to apply a template according to the needs of that particular case. Consequently, what started as protocols and decision trees in the knowledge-based system era of the 1980s has gradually changed so that today they are called clinical guidelines and clinical pathways (21). Strict protocols have been challenged as "cookbook medicine," demonstrating that care cannot be prescribed from a distance.

Guidelines are compiled from medical knowledge. While medical knowledge is universal, clinical practice is local. Therefore, protocols need to take into account the local circumstances. Unfortunately, a large part of medical knowledge is based on experience rather than on hard facts. It has even been claimed that only 40% of medical procedures are based on evidence. "Evidence-based medicine" is one attempt to improve that ratio (7).

The challenge of a physician is to be up-to-date on what are current "best practices" in medicine. Medical textbooks, journals, and other reference materials are the stores of that knowledge. The question is how to access the right source at the right time. Today a lot of this is available on the Internet and on CD-ROMs. Additional efforts are made to improve accessibility through indexing and by setting up knowledge servers. The fame of MYCIN (22) and other favorable conditions led to a boom in medical knowledge-based systems research in the 1980s. As results usable for clinical practice were slow to materialize, interest faded. In hindsight, the reasons for failure were twofold. First, patients are whole human beings and can only in rare cases be treated within the limits dictated by the knowledge-based system. Building systems based on all medical knowledge was, and is still, impossible. Second, clinicians are responsible for the diagnosis and treatment of patients. They cannot be replaced by a machine. A number of approaches were developed to address this, like critiquing and case-based reasoning. However, they did not meet the expectations or the acceptance of clinicians. Today, knowledge-based decision support is used only in embedded systems like diagnostic ECG machines. Similarly, neural networks and fuzzy systems are finding applications into which they can be embedded, thus hiding their existence from the user.

In addition to making medical knowledge readily available in a clinical setting, there is another challenge related to communication between clinicians. A major part of patient data collected during a clinical episode is unstructured. Referrals and discharge letters are summaries of the case accompanied by structured elements like laboratory findings. Each clinician has an individual way of writing these and must include the whole picture with context for them to be useful to other clinicians. Several ways have been developed to summarize this information. These include, among others, ICD-10, SNOMED, Read codes, and diagnosis related groups (DRGs) (5,6,8,23). Some years ago two major projects were launched on both sides of the Atlantic to develop "translators" for communication between clinicians—Unified Medical Language System (UMLS) and Generalised Architecture for Languages, Encyclopaedias and Nomenclatures in Medicine (GALEN), respectively (24,25). The problem they are facing is the same that all those working in medical informatics face. They cannot change medicine; they can only support its advancement. Consequently the path to such translators is a long one and requires among other things progress in the area of evidence-based medicine.

Electronic Patient Record

An integrated electronic patient record that is available anywhere and at any time to those authorized has been the (almost) "holy grail" in MIS research and development for years. Having the relevant parts of patient data available at the point of care is, of course, necessary. The questions, however, are first, which comes first, the electronic patient record or the interoperable MIS environment producing that integration and making data accessible, and second, what is needed to make the integrated patient record clinically useful. Integration can, of course, always be accomplished by a data repository technique, where all data are stored in one database. This is indeed the approach taken by several MIS vendors. However, the usefulness of such a data repository presupposes that the clinical domains involved will have the same interpretation of the data stored. Their domains need to overlap for those data to be useful. This, in turn, implies that such agreements exist and are implemented in clinical practice. The federation of the domain needs therefore to extend across the whole data store. This has large implications for the whole organization. In other words, the issue is not to procure an electronic patient record system, but to achieve the necessary degree of federation among and between the clinical activities to make full use of that system.

The architecture of an electronic patient record system is an issue in itself. There the goal is to provide enough structure and flexibility to allow intelligent storage and retrieval of patient data. In Europe CEN TC 251 has produced a prestandard for the architecture (26) and in the United States the Medical Record Institute is working for the same goal (27).

Resource and Management Information Systems

Care processes also have to be managed in order to use the available resources effectively. This requires assessment of what resources are needed and used in a certain clinical service chain and attaching costs to these. The goal is to gather enough data on how clinical service lines operate, in terms of outcomes and resource utilization, in order to optimize their use of resources and to optimize outcomes and costs. Activity-based costing, DRG, case-mix, and local variations thereof are forms of resource management.

Continuity of Care

In current thinking the process model of care delivery extends from the home of the patient/client to the care facilities and back to the home covering the whole care cycle. Continuity of care (seamless care) is necessary for high-quality care with optimal resources. This means that several service providers have agreed to collaborate in solving the problem of the patient/client. This implies the need for an information network integrating the service providers, the individual care plans, and patient data [community health information networks (CHIN) and regional information networks].

The concepts of and solutions for common services, clinical guidelines, electronic patient records, and resource management apply equally in this environment. The only difference is that, instead of one service provider, there are several who have agreed to collaborate according to an agreement. As the number of actors increases the development and implementation of an information-management strategy is more demanding.

Minimally the chain includes a primary care provider (general practitioner) and specialist unit (hospital). Increasingly nations are using general practitioners as gate keepers and as case managers for specialist services. The GP must then have an information system that assists in keeping track on how the care plan of the patient is being executed/modified, even when the patient has been referred to another service provider. Similarly, telemedicine applications support consultations between clinicians, thus reducing the need for patients to transfer from one site to another. Such applications naturally need to comply with national legislation on data privacy and secrecy.

Personal computers, the Internet, telephone networks, and wireless communication offer additional extensions to continuity of care. Certain medical procedures can be done in the home setting (home care). Patients themselves can perform certain procedures (self-care). The process paradigm of ordering resources for problem-solving is being turned around in order to recognize that the patient has a dual role as both a subject and an object of care. In the 5th Framework Program of the European Union, the health telematics activity revolves around the concept "citizen-centered care" (28). This also aligns with health-promotion goals of making citizens more responsible for their well-being and health (wellness). With mobile communication these services are available everywhere. Finally, for elderly people information systems mean solutions for independent living and security, thus extending their ability to remain in their normal environment when their physical and cognitive abilities are deteriorating.

Telemedicine

Telemedicine uses telecommunications technologies to deliver health care over distances. It provides diagnostic, therapeutic, monitoring, and follow-up activities as well as management, education, and training. While the explosion of interest in telemedicine over the past few years makes it appear new, telemedicine has existed for more than 30 years. Currently it overlaps with what is considered to be covered by the term *medical informatics* (medical information systems). Examples of issues that overlap are regional systems, the integrated electronic patient record, and applications using the Internet. A partial explanation of this overlap is that telemedicine is promoted by teleoperators who are seeking means to add value to their basic services. The medical information systems industry is more fragmented for reasons explained elsewhere in this article. Teleoperators approach health care from the bottom up [from the telecommunications infrastructure toward the application layer, Fig. 6)]. The MIS industry delivers applications and systems integration services. As health care delivery becomes more integrated and extends to homes and individuals the borders between telemedicine and MIS are disappearing.

The original meaning of telemedicine was "medicine at a distance." Developments in telecommunications, telematics, computers, and multimedia have amended this definition. Now the emphasis is on the access to shared and remote expertise independent of where the patient or the expertise is located, the multimedia nature of such contacts, and the transfer of electronic medical data (e.g., high resolution images, sounds, live video, patient records) from one location to another. Distances and geography are no longer obstacles to delivering timely and quality health care.

Teleradiology is the most often cited telemedicine application. Other applications include dermatology, ophthalmology, pathology, psychiatry, transmission of images and signals generated by ultrasound and endoscopy and by physiological transducers for diagnostic and monitoring purposes (29).

Taylor (30,31) separates telemedicine into systems and services. The first deals with the technology needed to deliver the second. Telemedicine is still mostly in the technology phase. Numerous experiments and pilots have been conducted (and some are still running) that have established that the technology works. However, because they have been mostly closed environments with special funding, the pilots have not survived in real life. Once the pilot is over it has proved to be extremely difficult to build a convincing case to continue with the service on a real cost basis. Teleradiology, however, is an exception. There is evidence that it is cost-effective at case loads that are realistic in typical clinical practice. As teleradiology has been around the longest it is reasonable to assume that as other telemedicine services mature in the coming years they will diffuse into clinical practice. The fact that health care services are becoming integrated on community and regional basis and that the telecommunications infrastructure necessary to support this change is growing also strengthens the case for telemedicine.

A telemedicine system consists of input/output stations and a communications channel. The performance requirements depend on the application. In the case of teleradiology these include:

- Image capture, either directly from digital imaging modalities or indirectly from films scanned with digitizers.
- Transmission of image and associated patient data through a data channel. Depending on the speed requirements, the channel can be an ordinary phone line, an ISDN line, or even ATM. Satellite communications is used.
- Because the size of a digitized X-ray image file is large (an image of 1000 pixels and a 12-bit gray scale means that the file size is 12 Mbit) and the bandwidth of the data channel is limited, the files are usually compressed at the sending side. Efficient compression algorithms are lossy—that is, all image detail cannot be re-created during decompression. Much effort has been invested into researching what compression ratios are acceptable in various radiology applications.

- Workstations to display X-ray images and associated patient data. The features needed are different at the sending and receiving sides.
- User interface to operate the system.
- Teleradiology systems are either standalone or integrated with other ISs at both ends. In such cases, image and patient data communications is usually based on DICOM and HL7 standards, respectively.

Diagnostic and therapeutic telemedicine services include teleconsulting, teleconferencing, telereporting, and telemonitoring (31). Although experiments and pilot projects for numerous telemedicine applications are being conducted, the development of telemedicine services used in routine clinical work has been slow. This is explained by a number of factors, the most important of which is that a telemedicine service is an add-on to existing services. Therefore it must either offer benefits that cannot be disputed or replace a less cost-effective service. The argument that it provides a means to deliver care over a distance is not enough. It must be supplemented with facts about quality, acceptance, and cost in comparison with the services it is replacing or augmenting. So far there is not much data available on the utility of telemedicine with the exception of teleradiology (32). Reimbursement polices are another barrier for telemedicine. However, with community- and regionwide integration of service providers, this barrier will probably disappear.

A further problem is reliability and liability. Can users trust what they access? Who is responsible if something goes wrong? When the expert consulted is a human being, the usual rules of practicing medicine apply. For servers available through the Internet, however, the situation is quite different. Consequently as this concern has been vioced mechanisms have been created to provide guidelines and certification of these servers. Health on the Net (HON) is one such service (33).

Data Confidentiality and Data Security

Confidentiality and security of patient data are issues that cannot be compromised. National legislation defines how the privacy of a person (even a patient) must be protected. Other legislation provides the framework in which health care is practiced. All MISs, MIS environments, and information management strategies must minimally provide what is required by the relevant laws (34). Some countries require that all software used in health care be certified that it meets the national regulations (35).

Organizations should establish an information risk management plan for the implementation of these requirements into operational processes and MIS. Elements to be included in such a plan are:

1. How authorization to access patient data is obtained from the patient (e.g., using individual health cards)
2. How access rights of health professionals are controlled, maintained, and verified (e.g., audit trails and strong authentication with electronic signature)
3. How patient data are grouped with different access rights
4. How patient data are secured (e.g., by encryption)
5. How the training and education of health care professionals and patients in these issues is organized

Data confidentiality however, is not a black-and-white issue. In real life and especially in health care, every situation that will arise cannot be legislated nor can the normative requirements be applied in all situations. Common sense must prevail in such situations.

THE FUTURE

The utilization of information technology applications in health care is influenced by progress in IT, medicine, clinical practice, and health care delivery. These elements are highly intertwined with one feeding the others. In IT the major trends are the Internet, Web technology, and mobile communication. Web browsers are an easy way to provide uniform user interfaces within an organization. Similarly, Extranets are a way for the organization to be in contact with its clients (citizens, patients) without compromising data confidentiality and security (although there are still doubts about the security features of Web implementations). Mobile communication, fueled by the explosive growth in cellular phones and value-added services, seems to offer a limitless range of applications.

However, these are just technologies. They need to be applied in a way that results in benefits for the clients/patients, users, and organizations. User organizations should be careful not to be too enthusiastic about the possibilities offered by new technologies. New technologies "obey" the life cycle of early adaptation by technology enthusiasts and then early adapters. These provide the testing ground to perfect the technology and to make it available at an affordable price to all. If the technology does not survive the tests of the early adapters it dies (36).

The process approach and the need to manage care jointly are pushing service providers toward collaboration in order to meet the needs of their customers and solve the problems of their patients effectively and efficiently. The scenario of Fig. 7 and Table 4 rests with the idea that IT can integrate data

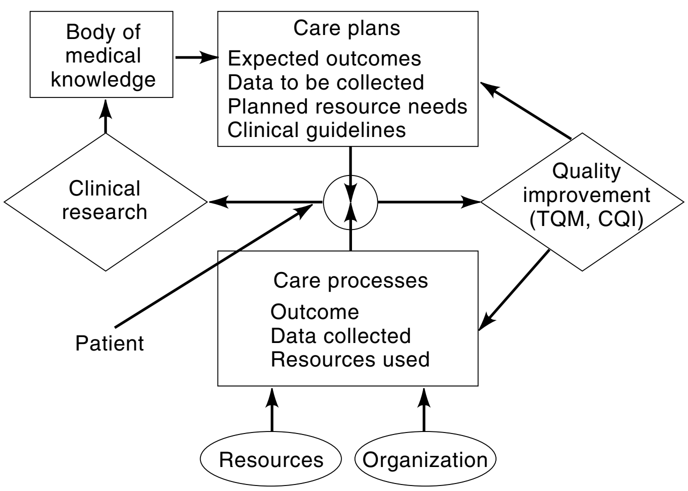

Figure 7. A care scenario combining care processes, plans, and clinical guidelines, and with quality improvement both at the organizational and medical research levels.

Table 4. Characteristics of a Health Care Environment of Today and the Future

Today	Future
Disease and illness management	Health promotion and wellness, independence and security
Hospital-based care	Virtual care (front lines and centers of excellence)
Authoritarian and profession centered	Client-centered care
Patient record centered	Seamless service chains, logistics, community health information networks (CHIN)

and make it and medical knowledge available in the right format anywhere and at any time. From the IT viewpoint, health care will become virtual and transparent.

The development of MIS applications that are transportable and integratable naturally starts with identifying user needs. User involvement in the development, testing, and evaluation phases is equally important. The concept of a user, however, needs to be viewed as widely as possible. This means that one should include all categories of users from daily end users to management. It also means that efforts should be made to involve more than one health care organization. It also means that when the resulting product is taken into use, its costs are offset by benefits and/or savings in other areas, thus justifying the investment in that specific product. According to Gremy and Sessler the key elements in this are the respect of professional identity and a mutual effort for mutual understanding (37). The medical professions should be empowered by the MIS applications instead of being forced into one working pattern.

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