PROGRESS OF INFORMATION TECHNOLOGY IN HEALTHCARE, CURRENT STATE, OUTLOOK TOWARD FUTURE

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ARTICLE HISTORY
Received 31 March 2013
Revised 12 June 2013
Accepted 26 June 2013
Available online 2 July 2013

KEYWORDS
information systems
HIS development
history
perspective of HIS
coding systems in healthcare

ABSTRACT — *Brief summary of reasons for development of Hospital Information Systems (HIS) is described. We mention different concepts of HIS development. Primary negative attitude of physicians to the invasion of information technology to hospitals has been slowly changed.*

Extended teaching of fundamentals of computer science at medical universities is very important for a new generation of physicians. Modern methods of e-learning allow using websites and medical atlases including presentations of surgical interventions in different branches of surgical medicine, physiotherapeutic methods, etc. Medical staff in hospitals may also profit from electronic tools used for education in medical informatics or for obligatory postgraduate courses.

Software producing companies are obliged to teach potential users how to use implemented information systems effectively. E-learning is a good method how to teach new employees who need to start using the system.

Telematics in health service and use of Internet data storages may be a trend in future development of information systems. Large amount of patient data in current databases is a big encouragement for expanded use of data mining and application of artificial intelligence methods in medical expert systems.

REASONS FOR MEDICAL INFORMATION SYSTEMS DEVELOPMENT

There were several good reasons for genesis and development of healthcare information systems. In the beginning it was necessary to make patient medical record more precise, to store large amount of data and to accelerate data transmission.

It was difficult to obtain in short time medical data from earlier treatments that were archived in paper form. It was tiring to wait for laboratory and other diagnostic results when they were prepared in laboratory and were just waiting for manual transport to demanding site. Laboratory practice was expecting rationalization of daily routine by implementation of specialized laboratory information systems connected to laboratory analyzers. Digital representation of images implied storing of those bulk data in high capacity storage with subsequent access to necessary images directly from medical departments [1]. Great attention was consequently paid to homogeneity and coding of data. Information systems started to be responsible for automatic billing to insurance companies. Existence of databases allowed fast access to stored data and have accelerated extended scientific research. Large databases became good source of data for medical publishing, e-learning material and excellent base for statistics. Building of decision support systems with well arranged outputs for medical decision making helped not only to clinicians [2] but also to healthcare managers to keep cost control in desired limits [3,23]. Special algorithms with elements of artificial intelligence may help to interpret laboratory data to physicians and to propose possible treatment. Systems are well prepared to help with calculations and sorting of patients to predefined categories. Their use for calculation of many different indicators like for example Glasgow Coma Scale [4], acute physiology score SAPS II [5], disease classification system APACHE II [6] or TISS score for patients treated on intensive care units [7] are well known among physicians. Implementation of information systems has increased substantially productivity of many departments – laboratories, imaging methods, functional examinations and consequently it increased competitive ability of those departments.

A BIT OF HISTORY

Medical informatics started to be developed in Czechoslovakia in early 1970s. In the beginning there was a lack of suitable computers and high capacity storages. An absolute inexperience of medical staff with computer technology was a great problem. It was also difficult to overcome mental barriers of physicians who had unsubstantiated fear of possible replacement of them by computers in the process of medical treatment (!). The situation continuously changed when a new generation of physicians with fresh basic knowledge of information technology started to work in hospitals.

Reasons for this change were:

1. Development and production of new very useful and respectable medical devices like CT, NMR, bedside monitors, modern ECG, laboratory and lot of other diagnostic and therapeutic instruments. All of them were equipped by computer technology.
2. It was possible to see medical information systems working and helping successfully in some hospitals. Information systems have brought new quality to physicians' work. Access to enormous amount of data was suddenly very simple and very fast. They made administrative work of physicians much easier.
3. A massive public education was going on.

To be successful in application of computers in healthcare information systems, it was necessary to establish an information center in some hospital. It was a Research Institute of Traumatology in Brno that was chosen in year 1975 to be a leading institute for development of hospital information systems in Czech Republic. First information system including signal analyses was realized there for intensive care units. It was a base for consequent development of Clinical IS.

First successful attempts of medical information systems development were done also in some other hospitals:

- Register of all patients in Benešov district including dispensary care was realized in Benešov Hospital.
- A very sophisticated Laboratory information system was developed in Hospital Bulovka in Prague.
- In University Hospital in Prague (Královské Vinohrady) was developed a Departmental information system.
- In Ostrava City Hospital there was realized an information system for resuscitation units.

Research Institute of Medical Bionics in Bratislava was a very important co-operating partner in Slovakia.

A conception of development teams was different. Developers in Brno considered a Clinical IS connected to all diagnostic departments a base of future Hospital information system. Development team in Bulovka Hospital considered a Laboratory IS a base of Hospital information system (HIS). Developers in Prague promoted a philosophy "a hospital equals a hotel" that laid stress to economical behavior of a hospital. A research team in Ostrava has paid a great attention to signal and laboratory results interpretation.

Conditions have changed after political changes in Czechoslovakia in 1989. Most of developers from hospitals and research institutes have switched to private business and they have established small software houses or have joined large and respected companies where they continued in development of medical information systems using their experiences from previous period. Hospitals have suddenly become obligatorily profit-making subjects. That was determining how to continue in development of HIS. Managements of software houses had to decide which program modules to prefer not to be in loss, as the development was extremely expensive. Lot of small companies also went bankrupt at that time.

It was evident already in year 1990 that hospitals, which wouldn't have suitable information system, could have great economical difficulties. It resulted in fact that every hospital has more or less functional information system at present, at least for billing of patients and obligatory reporting. Information systems are currently well accepted in hospitals. E-learning is a good method how to teach new employees who need to start using the system. Prepared manuals, animated presentations and e-learning courses are well accepted, especially by new users who didn't pass starting training after system implementation and therefore hadn't a personal contact to the training person. Particularly the nurses are employees, who migrate often from one hospital to another.

WHAT DID WE ACHIEVE?

We may state that since the end of 1970s we were able to collect large amount of patient data and medical data in general, to store and display them, we were also able to interpret some of them. But it was quite difficult to search and find relations between data in large databases. Data mining is a consequential branch of information technology that has good chance to be successful in this field.

Security of data is a very important attribute of hospital information systems. Backup and archiving procedures are on a very good level. Fast and large external memories allow quick access to archived data. We may expect that use of new technology of bulk external storages will yet shorten time of access to enormously large data in databases, for example images.

COMPARISON OF DIFFERENT ATTITUDES

There was an essential difference between information systems in Czechoslovakia and western countries before year 1993. Czech and Slovak developers were not obliged to pay attention to economical behaviour of hospitals. On the other side, processing of economical data, and particularly billing of patients, was a fundamental characteristic in western hospital information systems.

Law changes concerning financing of medical treatment in Czech Republic in year 1993 caused great changes in existing medical information systems. A constitution of health insurance companies and frequent changes of billing rules caused often headache to programmers of hospital information systems. It was a good decision of Czech parliament to authorize General Insurance Company (Všeobecná zdravotní pojišťovna – VZP) to determine billing rules and to develop list of registered medical activities and medication that are obligatory for all Czech insurance companies. Otherwise it would increase costs of keeping particular billing programs up to date enormously.

EXPERIENCES WITH SERVERS AND DATABASE

There exist two basic concepts of HIS: System with distributed database and with centralized database.

HIS with distributed database was very popular when database servers weren't fast enough to serve hundreds of terminals. Database was split to a set of servers each of them serving to a particular professional unit or department and connected together physically by LAN with a help of a communication center. If one of the servers was down from any reason, all the others were working independently. It was a great advantage. But it was painful for system people to administer a distributed database like this with all those necessary backups, prophylactics and other potential problems.

With improved performance of large computers it was more and more frequent to run HIS with centralized database and with hundreds of terminals, and later client PCs, connected to application and database servers. PCs have fully replaced earlier alphanumeric terminals. Their graphical capabilities make possible to share images across the hospital, which is a very appreciated feature in medical environment.

It was always important to choose a good brand-name hardware produced by respectable companies and a high-quality and robust operating system like UNIX, recently also LINUX, and their clones. Operating system Microsoft Windows wasn't accepted for a long time as a reliable operating system for a serious around-the-clock work in large medical information systems. But since version MS Windows Server 2003 it was considered to be a reliable operation system and is currently widely used especially in smaller applications like laboratory IS or outpatient IS.

A good choice of correct database is an important factor when we build a medical information system. Although the first attempts to construct medical information systems were based on simple databases like dBase, FoxBase, Clipper, later also FoxPro, it was soon evident that large information systems with lot of data need a powerful, large, fast and reliable database. The database should have optimal storage of data, should be on-line backed up or replicated, self-correcting and with acceptable costs of its licenses [8].

Database Caché, a product of company Intersystems [9], seems to be very favorable in medical information systems. Its data are stored in tree structure. This database is a successor to database concept MUMPS [27] that was developed and cultivated in USA and afterwards in Europe since the end of 1960s. It is very often used in medical information systems in USA and also in Europe because of its excellent ability to treat text information.

If the system works in a regular medical environment and the cache buffer is well adjusted, the database control system (DBCS) Caché ensures that up to 99% of data are transmitted to requiring program from the cache buffer without need to go physically for data to the disc. A clone of database Caché is available also for applications designed for operation system Microsoft Windows Server. Database Caché shows very good results on database servers in cases where databases like Informix (also designed for text treatment) have serious problems with performance.

Databases Progress and Microsoft SQL Server are also popular in Czech medical information systems. A highly respected database Oracle has a license policy and prices corresponding to tradition and reputation of Oracle Company and from that reason it may be too expensive for use in Czech healthcare service.

DATA CODING, CLASSIFICATIONS AND NOMENCLATURES

If we want from information systems to process data automatically, to sort them and produce correct statistics and if the principal data should be understood globally, it is necessary to use international coding systems and nomenclatures in a process of data acquisition. Electronic patient record is classified usually by principal diagnosis coded in International Classification of Diseases – ICD-10. The 10th version of this classification is obligatory to be used in Czech healthcare since year 1994 [10,26]. It differs substantially from 9th version. It is interesting that a change from ICD-9 to ICD-10 in USA is so painful

that they started with the change only in 2007 and still most of codes we see in United States today are version 9. We believe it is due to the fact that medical informatics in USA was in 1994 already widely applied, the transition from ICD-9 is very expensive and that is why most American providers have not yet upgraded to the ICD-10 system [11].

Czech authorities in cooperation with WHO have ordered to all providers of medical care to use International Classification of Functioning, Disability and Health – ICF since year 2010 [12,13]. It is another classification that allows coding of important facts describing patient's status and it is internationally understandable.

It is a pity that other international classifications like ICPM (International Classification of Procedures in Medicine), SNOP (Systematic Nomenclature of Pathology) or SNOMED (Systematic Nomenclature of Medicine) are used in Czech healthcare only rarely [14].

Obligatory use of wide range of lists published by Czech Ministry of Health is necessary for coding of data and regular reporting to NZIS (National Healthcare Information System) [15]. General insurance company VZP also publishes lists of medical activities and medication to be registered during patient treatment. Registered data are then used for billing to insurance companies [25].

DATA AND COMMUNICATION STANDARDS

Communication between two systems or subsystems or applications is a base for successful implementation of distributed architecture of large information system. Open architecture of particular systems prefers exchange of data and information structured in messages instead of direct access to other databases. Messages have standardized structure defined in data standard and both communicating subjects must accept their syntax and semantics.

It is very practical to use an open architecture when developing a new information system or subsystem. No software house produces whole range of subsystems that cover needs of all professional departments in hospital and it is often necessary to implement subsystems from different producers. And that is a moment when two companies have to agree on contents of exchanged messages. Structure of particular messages is then defined in the used standard for data exchange.

Historically, there were developed many partial or national standards for data exchange and this fact complicates process of globalization of healthcare. Czech national standard (DASTA) that was developed in 1990s and is being currently used, is an example of this undesirable effect. In spite of that, it is widely used in information technology in Czech healthcare service [16].

The worldwide used international standards in healthcare are HL 7 [17,18] and DICOM (Digital Imaging and Communications in Medicine) [19]. HL-7, an American standard for data exchange in healthcare, was a great model for Czech developers of DASTA. Conceptually, both of these standards are similar.

Digitalization of more and more departments working with images implies massive use of PACS (Picture Archiving and Communication System) [20]. PACS is a medical imaging technology that provides economical storage of images from multiple modalities and also convenient access to them. The universal format for PACS image storage and transfer is DICOM. The goal of DICOM is to reach compatibility and to improve effectiveness of workflow between imaging systems used in healthcare worldwide. The base for success of DICOM is a close cooperation of all top producers of medical imaging systems who voluntarily apply DICOM standard into their new developed systems and actively cooperate on improvement of DICOM standard [21]. DICOM enables currently integration of scanners, servers, workstations, printers, and network hardware from multiple manufacturers into PACS. DICOM has been widely adopted by hospitals worldwide as well as in Czech Republic.

WHAT DO WE OWE TO MEDICAL INFORMATICS

In the section of medical software that is engaged in administration we mustn't leave out free text processing. This is a very complicated task. Medical texts are written often in a hurry or in stress. They contain lot of typing errors, missed or distorted words and ambiguities that are interpreted correctly by a physician who reads the text in context with a previous text and thus may understand it correctly. Using simple algorithms for interpreting such a text may lead to very incorrect conclusions. That will need lot of effort in the future.

Voice analysis and its implementation to medical information systems will surely increase value of those systems in the future. Currently, it is still an unreachable goal "to speak with computer like with an intelligent creature with great knowledge". It would be very appreciated in situations when the physician hasn't his hands available for touching a keyboard, e.g., during operation, and needs some information that currently nobody knows and that is stored somewhere in the database of information system.

Also dictation of doctor letters to a secretary using information system technology is only a simulation of earlier voice recorder. A secretary types the acoustic record into the information system and it is stored in a form of typed text together with the voice

information in electronic patient record. Here is also a field for some brilliant solution in the future.

Never lasting changes in billing rules complicate life of programmers. It is a big challenge for good programmers to build billing programmes parametrically so that a changed rule could be set as a parameter and the current program would behave alternatively without changing it.

USE OF INTERNET IN MEDICAL INFORMATICS

Development and expansion of Internet is no doubt the most important breakthrough in information technology at the end of 20th century. An unexpected increase of network infrastructure and its availability at that time caused that original supposition of prof. Shortliffe [21] about connection of 200 millions of computers to Internet network in a first decade of 21st century was surpassed several times. Internet has offered an easy and fast exchange of clinical information. It allowed an easy on-line access to medical information, to knowledge databases and to educational tools of e-learning type. Information technology is accessible also to patients. They may make an appointment with their physicians; they have also access to their medical records stored in electronic patient record. They also have an access to professional information stored in Internet databases. We may say that a passive role of a patient in the system of medical care is changing.

PROFESSIONAL FIELDS IN MEDICINE WHERE INFORMATION TECHNOLOGY HAS IRREPLACEABLE POSITION

First area, a functioning of which we cannot imagine without information technology, is knowledge databases of particular medical branches. The databases contain examples of typical and above all atypical manifestation of diseases and methods of successful treatment. Databases of drugs and of special medical material function on the same principal. An on-line access into those large databases and existence of sophisticated and optimised search algorithms mean a great progress in medicine.

Second area is the use of information technology in fundamental medical research for acquiring of experimental and clinical data, their sorting and evaluation. Application of different technologies in clinical diagnostic and therapeutic process couldn't also be realized without using information technology.

Third area, that is currently the most dynamic application of information technology in medicine, is transmission and sharing of medical records in electronic form. Development and expansion of those applications of information technology gave rise to a new medical discipline – telemedicine, when a part of diagnostic and therapeutic processes is being realized without physical presence of a physician [22].

ARTIFICIAL INTELLIGENCE? EXPERT SYSTEMS?

Physicians and IT specialists have expected since 1980s from information technology a support of diagnostic decision-making process. Big effort has been made, and is still being made, to algorithm development of medical decision-making processes. Vagueness of those processes and thus a difficult algorithm definition are reasons of their rare application in practice. It resulted in current use of information technology first of all for supervision of standard diagnostic and therapeutic procedures and quality of care. We may suppose that corresponding to development of medicine, to expansion of medical knowledge base and to ability of information technology this field becomes also an important application of IT in medicine.

CONCLUSION

What can we expect from IT applications in the future:

- Extended use of tablets as communication tools in clinical information systems; it is a very practical device for data acquisition right at bedside.
- Increase of speed of access to data in databases; we may suppose that new generation of bulk capacity memory (SSD) as well as new electronic components will be continuously released for commercial use.
- Some other form of generally accessible electronic patient record than actually criticized IZIP.
- Verbal communication with an information system.
- Telemedicine development and expansion.
- Development and algorithm definition of medical decision-making processes with a clear goal: implementation of expert systems in selected medical branches.
- Development and expansion of e-learning and its application not only in schools with various orientations but also in other domains of human activities.

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