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Health information systems— past, present, future

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Summary In 1984, Peter Reichertz gave a lecture on the past, present and future of hospital information systems. In the meantime, there has been a tremendous progress in medicine as well as in informatics. One important benefit of this progress is that our life expectancy is nowadays significantly higher than it would have been even some few decades ago. This progress, leading to aging societies, is of influence to the organization of health care and to the future development of its information systems. Twenty years later, referring to Peter Reichertz' lecture, but now considering health information systems (HIS), two questions are discussed: which were lines of development in health information systems from the past until today? What are consequences for health information systems in the future?

The following lines of development for HIS were considered as important: (1) the shift from paper-based to computer-based processing and storage, as well as the increase of data in health care settings; (2) the shift from institution-centered departmental and, later, hospital information systems towards regional and global HIS; (3) the inclusion of patients and health consumers as HIS users, besides health care professionals and administrators; (4) the use of HIS data not only for patient care and administrative purposes, but also for health care planning as well as clinical and epidemiological research; (5) the shift from focusing mainly on technical HIS problems to those of change management as well as of strategic information management; (6) the shift from mainly alpha-numeric data in HIS to images and now also to data on the molecular level; (7) the steady increase of new technologies to be included, now starting to include ubiquitous computing environments and sensor-based technologies for health monitoring.

As consequences for HIS in the future, first the need for institutional and (inter-) national HIS-strategies is seen, second the need to explore new (transinstitutional) HIS architectural styles, third the need for education in health informatics and/or biomedical informatics, including appropriate knowledge and skills on HIS. As these

new HIS are urgently needed for reorganizing health care in an aging society, as last consequence the need for research around HIS is seen. Research should include the development and investigation of appropriate transinstitutional information system architectures, of adequate methods for strategic information management, of methods for modeling and evaluating HIS, the development and investigation of comprehensive electronic patient records, providing appropriate access for health care professionals as well as for patients, in the broad sense as described here, e.g. including home care and health monitoring facilities.
Comparing the world in 1984 and in 2004, we have to recognize that we imperceptibly, stepwise arrived at a new world. HIS have become one of the most challenging and promising fields of research, education and practice for medical informatics, with significant benefits to medicine and health care in general.

1. Introduction

''Hospital information systems have been in existence for almost two decades now. Therefore, it is possible to speak about their past. This contribution is intended to examine some of the features, which we could observe during this evolution, and it intends to project some of the present observations into the future''.

The text quoted here is from the year 1984. Twenty years before this, EuroMISE 2004 conference at Prague, Professor Peter Reichertz (1930—1987) gave in Brussels an outstanding lecture on ''hospital information systems—-past, present, future'' ([1]; among others referring to the work of Ref. [2]; see for a more recent publication of the author [3,4], see also Refs. [5—7]). Due to various reasons, I want to pick up this topic. It is slightly modified, as I will today, 20 years later, talk about the past, present and future of health information systems. The main reason for selecting this topic is that, not only in my opinion, this field is one of the brightest, most challenging and most promising fields of research, education and practice for medical informatics,[1] with significant benefits and consequences for medical statistics and epidemiology, and to medicine and health care in general.

Some places are more outstanding to give a talk than others. Among these places is the Aula Magna of the oldest university in Central Europe. Even before the University of Krakow was founded in 1364, the University of Vienna in 1365, and the University of Heidelberg in 1386, Charles the IVth, King of Bohemia, and later Roman Emperor, founded this highly esteemed university in 1348 at Prague as the first center of higher level education in this Holy Roman Empire [8]. Since its existence, Charles University had to play an important role as one of the cultural and intellectual centers of Europe, with influence to the whole world.

Also for my field, which is medical informatics [9—11] in a closer view, and informatics and statistics in the field of biomedicine and health care in a broader view, Charles University was and is of considerable influence. Let us remind of Rudolph Carnap (1891—1970), who was professor of natural philosophy at Charles University from 1931 to 1935. He was a leading member of the Vienna Circle, constituting its theory of logical empirism, one of the basic theories of our field [12]. Let us remember Antonin Svoboda (1907—1980) as one of the pioneers of computer science [13]. As founder of the department of mathematical machines in 1950 here at Prague, he was of considerable influence to the informatics development not only of Charles University and of the Czechoslovak Academy of Sciences. He strongly contributed to the theory of computing and was also dealing with early informatics applications in medicine. Last, but not least, let us think of Jaroslav Hajek (1926—1974) from Charles University and Zbynek Sidak (1933—1999) from the Academy of Sciences. They were pioneers in statistics, particularly in non-parametric methods and their asymptotic theory. Their book on the ''theory of rank tests'', published in 1967 [14], was for many of us a basic resource in the construction of statistical tests, based on ranks, in order to solve medical problems.

Looking at our societies today, we have to recognize that in the meantime, the change of our societies has continued rapidly. There has been have been even some few decades ago, with severe consequences for our societies and for our

[1] a tremendous progress in medicine as well as in informatics during the last decades [15,16]. One important benefit of this progress is that our life expectancy is nowadays significantly higher than it would

research. According to studies of the United Nations [17], we have to recognize that while in 1950, 8% of the world population was 60 years and older, it was 10% in 2000 and it will be 21% in 2050. While in 1950, 12 persons in the age between 15 and 60 years stood in relation to one person older than 60 years—-the so-called potential support ratio—-this ratio was 9:1 in the year 2000, and is estimated for 2050 to be 4:1. This progress is of influence to the organization of health care and to the future development of health information systems.

The intention of my talk is to point out future developments of processing data, information and knowledge in health care environments, as Peter Reichertz did in 1984, but from the viewpoint of today. The two questions to be discussed will be:

- which were lines of development in health information systems from the past until today and
- what are consequences for health information systems in the future?

But first, the terms health information system and hospital information systems will be introduced. My view expressed here is probably influenced (or, maybe, biased) by my own work in this field during the last 25 years, mainly done in university medical centers.

2. Health information systems and hospital information systems

Such complexes or systems of processing data, information and knowledge in health care environments I will briefly call health information systems (HIS, for more precise definitions see Ref. [18], pp. 26—33). So, hospital information systems are just one instance of health information systems, with a hospital as health care environment, respectively, health care institution. The aim of health information systems was and is as simple as relevant: to contribute to a high-quality, efficient patient care (e.g. [18], p. 30). This aim is primarily centered towards the patient, so it is a patient-centered approach and towards medical and nursing care, and the administrative and management tasks needed to support such care.

The relevance of 'good' HIS for high-level quality of care is obvious (e.g. [18], pp. 1—2), as without having appropriate access to relevant data, practically no decisions on diagnostic, therapeutic or other procedures can be made, with fatal consequences for patients. But HIS are also an important cost factor. Approximately, 10% of the gross domestic products of nations are devoted to health care, and approximately 5% to information and communication technology (ICT). The health care ICT industry has achieved considerable economical relevance (e.g. [18], pp. 1—9). Tendencies in increasing investments in health and in ICT, particularly in developed countries, can be expected. Having this in mind, we can recognize the relevance of systematically processing data, information and knowledge for the quality and efficiency of health care. Progress in the field of health information systems is rather directly correlated with more quality and efficiency of care, where ''with more efficiency of care'' may in future mean that care will remain affordable.

Let me briefly mention one example, pointing out the direct relationship of quality of HIS and quality of care, I had to deal with during my work at the Heidelberg University Medical Center (taken from Ref. [18], pp. 17—19).

Imagine the following situation: Ursula B. was pregnant with quintuplets. She had already spent more than 5 months in the Heidelberg University Medical Center. She had to spend most of this time lying in bed. During the course of her pregnancy, her physical problems increased. From the 28th week on, she suffered severe respiratory distress.

The pediatrician, who was also involved in her treatment, had the following question: what are the chances of the infants being born healthy at this gestational age?

He went to a computer, a 'health care professional workstation' available on his ward and in his office. Such a workstation can be used for a variety of tasks. It is connected to the computer network of the Heidelberg University Medical Center. The physician called up a 'medical knowledge server' and one of its components, a bibliographic database (MEDLINE). This database contains the current state of the art of medical knowledge worldwide. The medical knowledge server can be accessed at any time and from any of the more than 3000 health care professional workstations of the Heidelberg University Medical Center.

The following information resulted from this consultation of the medical knowledge server. Several publications stated that only slim chances exist for all infants to survive in good health. If they are born during the 28th week of pregnancy, the chance for survival is about 15%. In case of birth during the 30th week, their chances would improve to about 75%. Also, according to the literature, further delay of the delivery does not improve the prognosis of the quintuplets. The physician discussed the results with the expectant mother. Despite her respiratory problems, she had the strength to endure 2 more weeks. On January 21st, 1999, the quintuplets were born well and healthy at the Heidelberg University Medical Center. A team of 25 physicians, nurses and midwives assisted during the delivery. The costs for such a med-

ical knowledge server for a complete medical center are generally lower than the costs for one ultrasound scanner, provided that the information system of the medical center offers a minimum infrastructure.

A medical knowledge server, as an integrated part of a hospital information system could not be realized in 1984, at the time of Peter Reichertz' speech. This one was introduced by the Department of Medical Informatics of the University of Heidelberg in 1992. At that time, it was one of the first installations of its kind in the world. Nowadays, through global access to knowledge and through our networking capacities, such features can be implemented at low cost in every health care setting and can be used at any time at the health care professional's workplace.

3. Which were lines of development in health information systems from the past until today?

3.1. The 1st line: towards computer-based information processing tools

When we observe the reality of information processing in health care environments through the last decades, we could recognize that there has been a tremendous shift from paper-based processing and storage (see, e.g. [19]) to computer-based processing and storage [11,15]. This shift had disadvantages—mainly a higher technological complexity, and advantages—a significantly higher functionality and much better opportunities in using patient data or medical knowledge. Parallel to this development, there was an increase of data to be processed and stored, mainly due to the increase of diagnostic and therapeutic procedures, and due to new information technologies, allowing to process more data. This increase of data did not lead to a corresponding increase of health care professionals. Health care professionals of today usually have to deal with much higher amounts of data compared, e.g. to the health care professionals of 1984.

The amount of information processing in hospitals, especially in larger ones, should not be underestimated (see Ref. [18], pp. 11—12). Let us look at a typical Austrian or German university medical center. It is an enterprise encompassing a staff of approximately 6000 people, an annual budget of approximately D 500 million and, as a maximum care facility, numerous tasks in research, education and patient care. It consists of up to 60 departments and up to 100 wards with approximately 1500 beds and about 100 outpatient units. Annually, approximately 50,000 inpatients and 250,000 outpatients are treated, and 20,000 operation reports, 250,000 discharge letters, 20,000 pathology reports, 100,000 microbiology reports, 200,000 radiology reports and 800,000 clinical chemistry reports are written. Each year, approximately, 400,000 new patient records, summing up to 6 million documents, are created.

When stored in a paper-based form, this corresponds to an annual volume of approximately 1500 meters of paper records. Often they should be archived over a period of 30 years. When stored digitally, the annual data volume needed is expected to be around 5 terabytes, in both cases, including digital images and digital signals, and increasing. The computer-based tools of such university medical centers in the meantime encompass hundreds of computer-based application components, thousands of workstations and other terminals and up to a hundred servers (larger computer systems that offer services and functionality to other computer systems), which usually belong to a network.

In the following, I will mainly focus on the computer-supported parts of health information systems, as here the lines of development are the most interesting. In many of the health care settings, I am aware of the electronic patient record has already become the leading record, no more the paper-based one. We however have to recognize that currently we are still in a phase of transition. Twenty years ago, at the time of Peter Reichertz' speech, the paper- and film-based part of a hospital information system was the one being dominant in terms of volumes of data and functionality to support processes, therefore, denoted as the 'conventional' part. Today, we observe a certain dominance of the computer-based part of (e.g.) hospital information systems, while however the paper-based part is still existing, among others due to ease of use and legal reasons and has to be maintained. So, there is a highly redundant co-existence of paper- and computer-based information processing, often causing higher (maybe double?) costs and higher efforts for health care professionals to access and to use data.

3.2. The 2nd line: from local to global information system architectures

When working on computer-supported information systems in health care some 40 years ago, in the 1960s, 1970s and 1980s, our view as medical informaticians was mostly focused on small (functionally limited) applications in special departments of a hospital, e.g. at a laboratory, radiology or administration unit (e.g. [4], although there were always exceptions, e.g. [20]). We were mainly dealing with 'departmental information systems'. In the 1970s, 1980s and 1990s, we were already able to have broader views on such computer-supported

information systems, now considering the information processing in a hospital as a whole. We were mainly dealing with 'hospital information systems' [1,2,21—24]. Already starting in the 1990s and in this decade, we are concentrating our research and are starting to focus our practical work in considering information processing in health care regions, mostly in a rather global sense. For the first time, we are really having the chance to broadly explore patient-centered information processing in 'health information systems' [25—33].

Patient-centered information processing was our aim from the beginning on, not institution-centered processing, which may lead to sub-optimal results with respect to quality and costs of patient care. The development from local to regional and global architectures fortunately correlates with the intentions of many health care authorities to improve quality and efficiency of care through disease-oriented, not institution-oriented care strategies.

Such departmental, hospital and health care systems were having specific information system architectures and infrastructures. Peter Reichertz has given in Ref. [1], examples of the architectural style of the ''Medical System Hanover'' at that time (Figs. 1 and 2).

As architectural styles, we could identify, e.g. more centralized or more distributed styles [38—44]. Questions in all architectures were, e.g. technical availability, quality of data, referential integrity of patient data, data modeling, interfacing, quality of functionality, in particular concerning the support of health care processes and problems of transcription. Last, but not least, the ease of use of computer-based tools regarding data input and data usability for health care professionals in their daily work with the patient always has been of relevance.

Until today, many of us feel that health care professionals as users accept the necessity of computer-based health information systems and see their benefits, but they are not really content. Besides the reason that computer-based information processing tools are still improvable, especially with respect to the ease of use and the ease of data input, the increasing amounts of data in medicine and health care, as mentioned in the last section, may also be one of the reasons for this unsatisfactory situation.

Let me take as example for regional HIS architectures the so-called health@net project at Innsbruck, Austria [45,46]. In this project, we developed a stepwise approach to replace the paper-based transmission of medical documents with standardized electronic communication. In the first of three steps in total, we established an electronic communication of discharge letters and diagnostic results between existing information systems

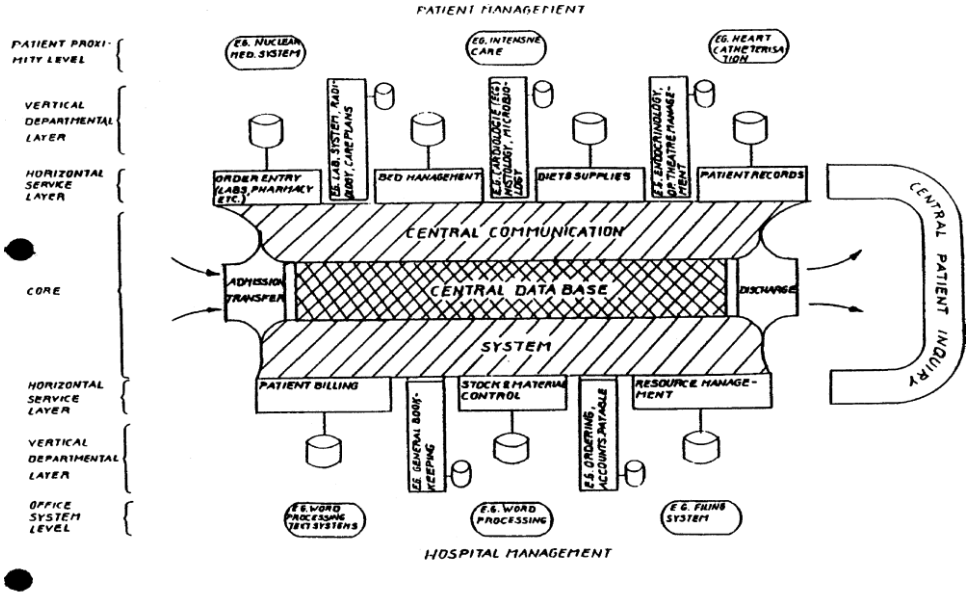

Fig. 1 Example of a visualized information system architecture, here of the computer-supported part of the hospital information system of the Medical School Hanover from 1984 ([1], p. 9).

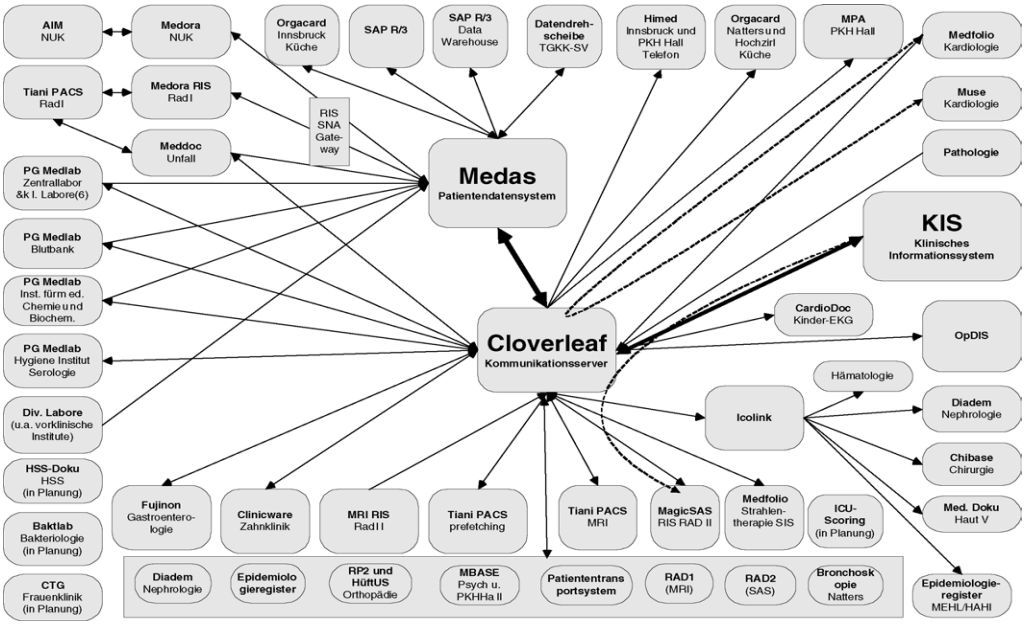

Fig. 2 Example of a visualized information system architecture, here of the computer-supported part of the information system of the Innsbruck University Medical Center from 2002 ([34], p. 31), using the three-level graph-based meta model (3LGM, [35,36], see also Ref. [37]), here to describe the so-called logical tool layer.

of different health care providers in Tyrol, Austria, over two channels: in the form of cryptographically signed S/MIME email messages to members of Austrian health care networks and via a secure web portal system.

In the meantime (since June 2003), documents of the electronic patient record including, e.g. discharge summaries, radiological images or lab results of the TILAK hospitals are available globally to health care professionals via special secure web services. This gives us the opportunity in particular to support patient-centered care in the Tyrol and related German, Italian or Swiss regions, beyond the limits of one health care institution and even beyond the limits of a nation. An outline of the health information system architecture, extending Fig. 2, is presented in Fig. 3. Of course a couple of problems, also legal ones have to be treated and solved.

3.3. The 3rd line: from health care professionals to patients and consumers

At the beginning, computer-supported health information systems were primarily intended to support health care professionals, mainly physicians, as well as administrative staff in hospitals [1,2,22,23]. Later, there was a focus also on nurses. Since several years, we can recognize that health information systems now also will have to directly support patients, their relatives, respectively, all people with health questions and problems—often denoted as health consumers [3,26,47—50].

3.4. The 4th line: from using data only for patient care to research

Another shift was given in the use of data in such information systems. Even until the last decade, there was an almost exclusive use of HIS data for patient care and administrative purposes, with some use for quality management and controlling [2,21,27]. Now we are having the ability to extend the possibility of using data, primarily used for patient care, also for health care planning and, above all, for clinical research [9,15,51,52]. This possibility will have a continuous influence to medical statistics and epidemiology, in terms of probably different study designs and methods for data analysis.

3.5. The 5th line: from technical to strategic information management priorities

While for computer-supported information systems technical problems were the main focus from the 1960s until the 1990s, we could observe a shift starting about 10—15 years ago. Organizational problems, social issues and change management aspects became to be identified as relevant and

were even becoming dominant for the field of health information systems ([53—55], see also Refs. [56,57]). At the same time, it was recognized that there is a need for managing information systems. In particular, the strategic, long-term information management was finally regarded as a serious and necessary task [58]. In the meantime, strategic information management plans have become part of the business plans of many hospitals. Methods like strategic alignment or portfolio management are being used for strategic management. Other methods, for example to analyze and assess business processes, are now also taken for tactical information management (see, e.g. [18], chapter 5).Let me mention as example the strategic IT plan 2003—2007 of the Tyrolean State Hospitals (TILAK), including the Innsbruck University Medical Center [34] and let me quote the English version of the management summary:

The following IT-strategy 2003—2007 summarizes the current state and the planned development of information technology (IT) and information processing of the TILAK. It updates the past IT-strategy of the TILAK.

Objectives

The aim of the IT-strategy is to, in the best possible way, support workflows in medicine, nursing, science and management through the implementation of suitable information and communication technologies, as well as by providing adequate procedures for patient care, management and administration.

With this, the IT-strategy supports the general goal of the TILAK of ensuring timely medical care for the Tyrolean population, which also meets demands with regard to medical education, and research in the clinical areas of the Medical Faculty of the University of Innsbruck implemented at the Innsbruck University Hospitals.

Providing timely information technologies will continue to be seen as a strategic instrument with regard to the best possible health care and as basis for improved management and scientific research.

The present state

The IT solutions of the TILAK, as seen from a national and international point of view, have reached a high niveau. For example, through the development of an enterprise wide integrated hospital information system, the path to an encompassing electronic patient record, which is available, everywhere was begun early. All radio diagnostic departments are equipped with a picture archiving and communication system (PACS). This enables widespread film-free work within the TILAK buildings.Current weaknesses exist in the many independent special IT solutions with the integration and support expenses which are tied in with them, as well as in the minimal IT support of the patient-based order entry. The proportion of electronically available documents needs to be increased when compared to the conventionally available documents.

Planned development

IT will considerably change medicine and healthcare in the next 10 years. There are great expectations of IT tied in with the great expectations in view of the increase in quality and efficiency of patient care. Demographic development and medical advancement will furthermore produce great cost pressures on healthcare. With regard to this development, the following goals will be pursued in this IT-strategy:

- integrated, institution-wide care through the networking of all service providers;
- patient-centered documentation and communication based on an extensive electronic patient record, as well as;
- the standardization of medical process through the presentation of knowledge as well as the integration of knowledge in standards and decision support systems.

In order to reach these goals, projects should be carried out in the following areas:

- expansion of the clinical information system (for details, see Ref. [44]), more precisely the electronic patient record;
- further development of knowledge management;
- new medical department systems;
- a reduction of the number of existing medical department systems through the expansion of HIS functionality;
- new functions for business management, logistic and technical areas;
- new technologies (e.g. digital signature, integration of speech and data communication);
- expansion of IT infrastructure (e.g. development of network infrastructure, introduction of mobile terminals);
- development of regional networks, as well as;
- impulse projects (e.g. the use of robotics and 3D image visualization).

IT organization

The organization of information management has already been adapted to the aims presented in this IT-strategy. On one hand, the organization encompasses a definition of a strategic, tactic and operational level, and on the other hand, a combination of internal and external areas in the sense of cooperative outsourcing.

For strategic information management, the TILAK board and the Director for Information Management receive support from the Strategic Information Management Board. In the future, information management will also be further developed through work distribution to both internal and external competencies, where the role of the project initiator, project management and first-level support will primarily occur internally and system development, computer center operations and education will for a larger part be performed by outsourced institutions.

One of our challenges of today is that we have to set up information system strategies not only for hospitals or other health care institutions, but also for regional, national and international settings [59—61].

3.6. The 6th line: inclusion of new types of data

With a higher degree of use of computer-supported information processing tools, not only the functionality of the computer-supported part of HIS was extended. Correlated with this development, as a continuing process, the types of data to be considered continuously increased. Were it in the 1990s the possibility to broadly consider images, in particular from radiology, in addition to alphanumeric data, we are now having new types of data on the molecular level, e.g. as DNA or protein data [62—66].

3.7. The 7th line: inclusion of new technologies

Another continuing process in this evolution was the increase of functionality in computer-supported health information systems. Today, we can observe new extensions by the use of so-called enabling technologies for health monitoring. These technologies enable us to continuously monitor the health status of patients with unobtrusive, non-invasive technologies, e.g. as wearable devices. Such wearable devices may range from micro sensors, integrated in textiles, through consumer electronics, embedded in fashionable clothes and computerized watches, to belt worn personal computers with head mounted display [67] (see also Refs. [29,57]). With appropriate sensors data can be measured continuously, not only at discrete points in time, and without manual intervention. With the help of such sensors and with ubiquitously available computing facilities, local (pre-) processing is possible as well as a later, maybe wireless transfer to monitoring centers, at least in terms of reporting on exceptional conditions of a patient and in raising alarms in case of critical situations. Here, we can identify new possibilities of organizing care and treatment in a way that might be more convenient for our daily life and may support us to keep living in our social environments. It may be suitable and affordable for aging societies.

3.8. Summarizing the HIS development

Comparing our globe at the time of Peter Reichertz in 1984 and the one we are living in today in 2004, we have to recognize that we imperceptibly, stepwise arrived at a new world. Peter Reichertz

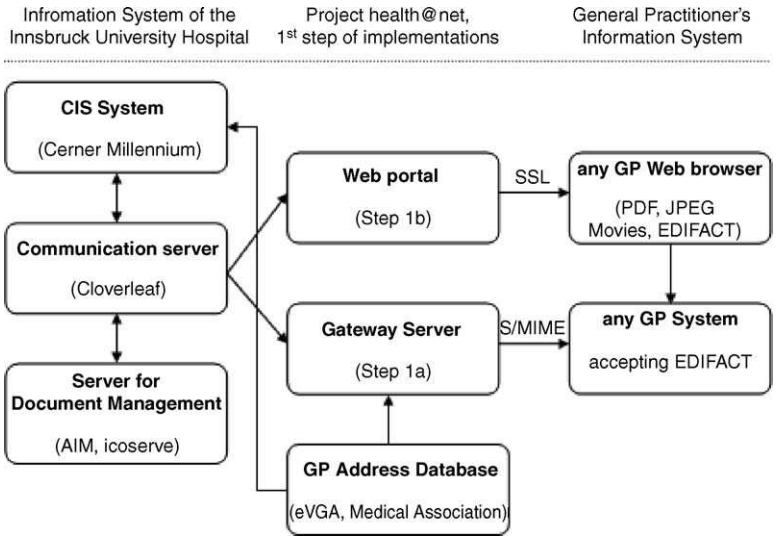

Fig. 3 Logical tool layer of a three-level graph-based meta model (3LGM) of relevant health@net system components. Medical documents from the clinical information system (CIS, in Fig. 2 denoted as KIS) are addressed to their receivers (according to the eVGA-Server, an LDAP address directory which is hold by the Austrian Medical Association) and transferred either to a gateway server (which delivers the documents directly into an inbound directory of the GP-system over the commercial health care networks, step 1a) or onto a server for document management which provides the files for a secure Web portal (step 1b) and the GP's Web browser also directly into the inbound directory of the GP-system (from Ref. [46]).

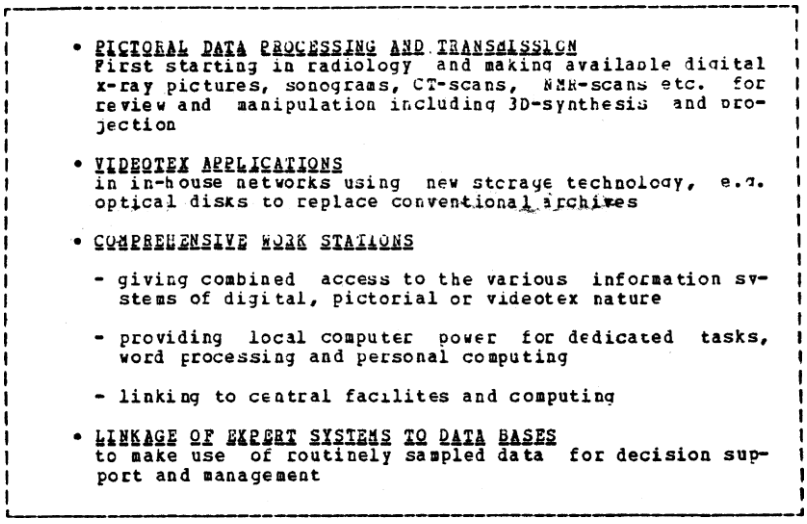

Fig. 4 Highlights of new technologies in hospital information systems, from the viewpoint of Professor Peter Reichertz in 1984 ([1], p. 30).

foresaw many of the core developments in health information systems (Fig. 4), but the scope was even broader and the pace even faster than he probably expected. Our daily life looks different today compared to 20 years ago. The same can be observed for the working environment of health care professionals, or for patients and health consumers.

Fig. 5 tries to visualize the first line of development, described here, on the growing amount of data to be stored and processed, in particular in the computer-based part of health information systems. Fig. 6 tries to roughly visualize those aspects of this development, as mentioned in lines 2—7.

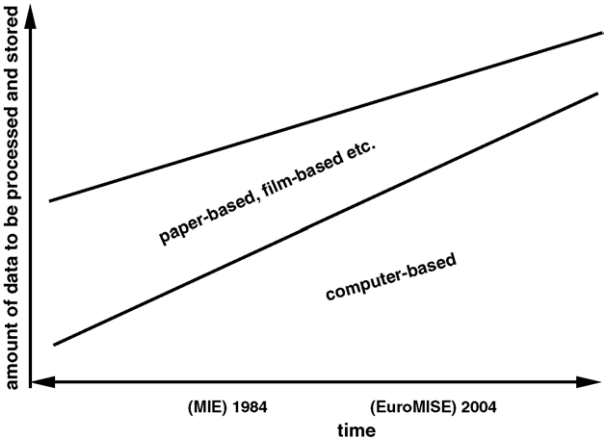

Fig. 5 Roughly trying to visualize the tendency towards computer-based information processing tools, dealing with a steadily growing amount of data in health information systems.

4. What are consequences for health information systems in the future?

4.1. The 1st consequence: the need for institutional and (inter-) national HIS-strategies

It is obvious, at least from my point of view, that strategic information management has now to be considered as an important task in the continuing process of maintaining and improving health information systems, in order to improve health care. It has to be implemented not only in health care institutions such as hospitals. Institutional information management strategies will have to be accompanied by regional, national and international strategies.

Strategic information management should now consider the developments mentioned before: on the global access to HIS, the extended HIS users including health consumers, the extended use of data including research, the new types of data and the health monitoring opportunities.

Conflicts will arise and will have to be solved. There will be promises and perils [68—70]. We have to find a balance to preserve privacy and to get the necessary support by ubiquitous computing resources for our health and quality of life.

4.2. The 2nd consequence: the need to explore new architectural HIS styles

It also seems to be clear, at least I am convinced, that architectural styles of these new health

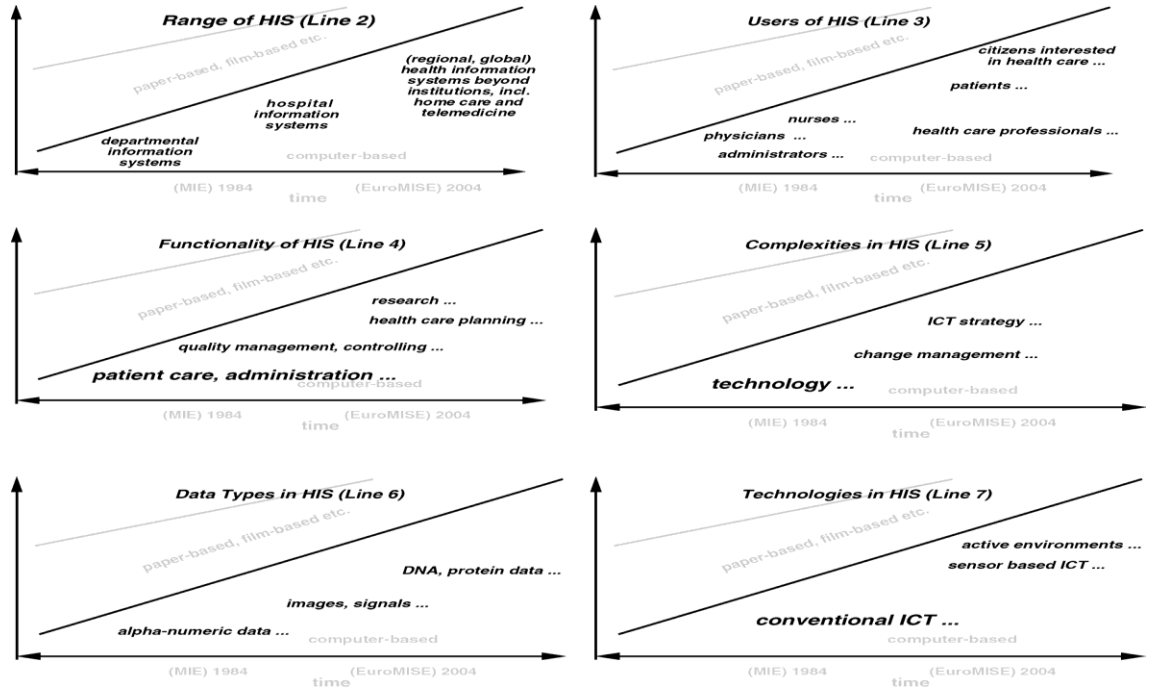

Fig. 6 Roughly trying to visualize the lines of development of health information systems concerning range, users, functionality, complexity, data and technology, based on the general tendency of a growing amount of data to be processed and stored, as described in Fig. 5.

information systems will again change in the now global environment (see, among many others, e.g. [71—74]). Besides the need for research (see Section 4.4), this has to be considered also and already today for the practice of information processing and information management.

Traditional institution-centered architectures will probably not be adequate, when dealing with regional up to global 'transinstitutional' information system architectures and infrastructures. This development will fortunately lead to more patient-centered (not institution-centered) HIS architectures. We will have to explore architectures, providing reliable services in the conflicting field of being less redundant, less transcriptive, and functionally more lean, but not too sensitive for local, regional or even global blackouts. Development and investigation of adequate transinstitutional information system architectures and organizational frameworks that support patient-centered, shared care will among others include exploring networking care facilities in health regions (e.g. hospitals, practices), diagnostic and therapeutic telemedicine, as well as home care. Considering the population development mentioned at the beginning, finding appropriate architectures will be of outstanding importance for the future of health care and so for all of us.

A final question to us as information system 'architects' is: what is 'just' functionality and what is great architecture, inspiring people? When does architecture as just conventional architecture end, and when does it really become art? Concerning great HIS architecture, I have the impression that

we information system architects are still centuries behind the architects of buildings. And let us keep in mind a sentence from Professor Francois Grémy, one of the founders of our field: ''any technology sets a relationship between human beings and their environment, both physical and human. No technology can be seen as merely instrumental. This is especially relevant when dealing with large automatic information systems, developed to contribute to the management and integration of large organizations, such as hospitals'' [75].

4.3. The 3rd consequence: the need for education in health and biomedical informatics

Another immediate consequence, in my point of view, is the need for appropriate education in medical informatics, respectively, health informatics or biomedical informatics. Because of the mentioned progress in informatics, including the described developments in health information systems, educational courses and even programs are needed, in order to have well-educated health care professionals or even health informatics/medical informatics specialists, with sufficient knowledge and skills to systematically process data, information and knowledge in medicine and health care (see, e.g. [76] as one of the latest examples). Let me especially mention the educational initiatives of the European Centre for Medical Informatics, Statistics and Epidemiology (EuroMISE Centre) here at Prague [77], today celebrating its 10th birthday and having been established 10 years after Peter Reichertz' lecture on the past, present and future of hospital information systems. Because of this need for education, the International Medical Informatics Association (IMIA) developed and published recommendations on education in health and medical informatics [78]. Lectures [79] and practicums [80] on health information systems should play an important role in such educational programs, as knowledge and skills in this field are of high relevance for health/medical informatics graduates (see, e.g. [81]).

4.4. The 4th consequence: the need for research in health and biomedical informatics

Health information systems are in a phase of rapid development, with many questions being still unsolved in terms of architecture, functionality and management. As in my view, these new types of systems are urgently needed for reorganizing health care in an aging society, there is a significant need for research in various areas of health and biomedical informatics. Some research questions could be mentioned in Section 3. For a rapid and successful progress on health information systems, it seems to me of particular importance to do research in the following fields:

- development and investigation of appropriate transinstitutional information system architectures supporting patient-centered, shared care, from networking care facilities in health regions (e.g. hospitals, practices) to home care including, e.g. diagnostic and therapeutic telemedicine, health monitoring, the use of ubiquitous ICT infrastructures and providing secure authentification;
- development and investigation of methods for the strategic management of health information systems, especially concerning information processing in health care regions, including;
- development and investigation of methods for modeling and evaluating health information systems as well as studying HIS properties through evaluation studies;
- development and investigation regarding comprehensive electronic patient records, providing appropriate access for health care professionals as well as for patients, supporting patient-oriented use of patient data in the broad sense as described here, e.g. including home care and health monitoring facilities, and also facilitating clinical and epidemiological research and health care planning;
- investigation of powerful, innovative ICT tools for the various users of health information systems;
- development and investigation of methods for medical data analysis ('medical data mining') based on the new information system architectures and electronic patient records and considering the broad variety of data types including, e.g. image and DNA data.

5. Conclusions

Let me summarize. Modern information processing methodology and information and communication technology has strongly influenced our societies, including their health care. Twenty years after Peter Reichertz'lecture on the past, present and future of hospital information systems [1], we can recognize that institution-centered hospital information systems are developing towards regional and global health information systems, with new, strongly extended functionalities and tasks.

As a consequence, more than ever, medical informatics is needed for an efficient development and strategic management of these new health information systems. Having the possibility of doing research and education in this field, or to contribute to its practice is a great opportunity and responsibility, as it gives the chance to contribute to the quality and efficiency of health care at a very prominent place. Twenty years after Peter Reichertz talk, we may redefine the aim of health information systems as to contribute to a high-quality, efficient health care, now for patients and consumers and for medical research.Health information systems have to be devel- oped and explored that enhance opportunities for global access to health services and medical knowl- edge. Informatics methodology and technology is expected to facilitate continuous quality of care in aging societies. Ubiquitously available computing resources and networks, existing worldwide for the transmission of all varieties of data, will allow us to consider new types of information systems for health care, including new kinds of health monitoring and also new opportunities for the analysis of biomedical and health data. These transinstitutional information system architectures and infrastructures will, when appropriately designed and adequately strategically managed, provide new opportunities for the whole field of biomedical and health informatics as well as of biomedical statistics and epidemiology. As in most areas of the sciences, let us remember that we need high-quality evaluation studies to learn, what we really have achieved and what we could do better. Last, but not least, these new opportunities for the systematic processing of data, information and knowledge in medicine and health care may considerably contribute to the progress of medicine and the health sciences as well as to the progress of informatics in general. And let us keep in mind that (bio-) medical informatics, health informatics, as well as statistics and epidemiology are aiming not for more technology, but for more and better care, a care that is affordable in aging societies. In the end only health and the well-being of individuals is what counts here.

Acknowledgement

This EuroMISE 2004 symposium has been organized and initiated by many persons, but one is out- standing. It is the initiator of the European Centre for Medical Informatics, Statistics and Epidemiol- ogy, Professor Jana Zvarova. In her never ending engagement, despite sometimes difficult political and economical constraints, she was always a promoter of our field, convinced that good science and good education in medical Informatics, statistics and epidemiology will contribute to better health and to the progress of the sciences. Her scientific achievements and her achievements here at Prague are really outstanding.Because of this reason, the University for Health Sciences, Medical Informatics and Technol- ogy (UMIT) at Innsbruck, Austria, decided to honor Professor Zvarova with its University Medal. Let me quote from the certificate: for her outstanding achievements in the field of Medical Informatics, Statistics and Epidemiology, the executive board of UMIT has decided on January 14th, 2004, to award the University Medal of UMIT to Prof. RNDr. Jana Zvárová, DrSc., Director of the European Centre for Medical Informatics, Statistics and Epidemiology (EuroMISE Centre) of Charles University Prague and Czech Academy of Sciences, to be handed over during the International Joint Meeting EuroMISE 2004.

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