Future Development of Medical Informatics from the Viewpoint of Health Telematics

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Keywords
Integrated care, decision support, eHealth, electronic patient record, usability, knowledge management

Summary
Objectives: The transformation process of the health care systems in most countries in direction of integrated care needs the support of information and communication technology. The central element of this development is the electronic health care record. But there are many other applications around this record and the functionality and usability of these systems has to be improved and extended.
Methods: A system-analytic approach to integrated care is used to analyze the possibilities and the role of information and communication technology in current and future health and social care systems.
Results: The key elements of the improvements in the next years are the integration of evidence-based knowledge in the care process, the improvement of the usability for patients and health care providers, the development of pro-active systems for decision support, the support of the mobility of patients and the activities of daily living, the integration of data form molecular biology, semantic interoperability and last but not least the processing and analysis of these data. In a series of tables requirements of the functionality of eHealth applications are summarized.
Conclusion: Research in medical informatics has to focus on strategic concepts and how to transform the demands of a modern integrated health and social care system into user-friendly, secure and efficient ICT solutions and to support the citizen's responsibility for her/his own healthcare. But there is also a high demand for research to improve the technology of ICT systems in health and social care.

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Methods Inf Med 2009; 48: 55–61
doi: 10.3414/ME9130
prepublished:

Introduction

Due to many reasons, like the aging population, financial pressure, new technologies etc., the health and social care system will change substantially within the next years. The keyword for this development is "integrated health care". Therefore new tools are necessary to manage the care processes within and between healthcare providers. The challenge for the information and communication technology (ICT) and for medical informatics (MI) is to develop the appropriate tools for an integrated health and social care system. Health care will be used as a general term further on and includes also social care.

There are many, many different definitions of health telematics [1], which also reflect the many different tasks to be fulfilled. Very often and very common health telematics is called eHealth to show the importance of e-technologies for health care. A very simple definition is: "eHealth is connectivity" [2]. eHealth encompasses all of the information and communication technologies (ICT) necessary to make the health system work. eHealth are new business models using technology to assist healthcare providers in caring for patients and providing services [1, 3]. Health telematics or eHealth can be considered as a synergism between informatics, telecommunication and health care. eHealth is the synergistic effect between modern knowledge-based medicine and ICT. It is not the sum of these components, it is the product. From a process viewpoint eHealth means: to connect, to communicate and to cooperate in the health and social care sector using ICT. eHealth encompasses a lot of applications with the electronic health care record in the center [4] and many further applications like telecare, telehealth, telemedicine, mobile health care etc. around it [5].

For the development of eHealth not only technical aspects but also the development and the transformation of the health care system has to be considered. The driving force behind eHealth is not technology itself, it is the necessity and the chance to improve the health care system, to make it more efficient, effective and safe. eHealth research has to include public health research and public health research has to integrate the developments of eHealth. High-quality health care is a process which depends very strong on data, information and knowledge which have to be available at the point of care about the right person and eHealth has to provide the tools to support this process.

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In this paper some ideas and concepts for the future development of health telematics in the next years will be presented. Starting from the concept of integrated care processes supported by ICT and using a system-theoretic approach for eHealth applications the present and future functionalities are shortly described. Some of them, like knowledge management, usability, data processing, personalization and decision support are discussed more detailed.

Status Quo, Past and Present

The current health care system in most countries is a highly fragmented one and it is organized more from the viewpoint of the health care providers than the patient. In the last years eHealth research focused on documentation, archiving, identification and communication and technical and semantic interoperability have been in the center [6]. Medical informatics has not only focused on technology but especially with regard to quality also on organizational aspects and processes have been in the center of many publications. Although the work is far away to be finished now, e.g. if semantic interoperability, patient and health care provider identification, technical communication standards or the architecture of documents are considered, eHealth research has to be extended from documentation and communication to pro-active data, information and knowledge processing systems [7]. The information systems of tomorrow are pro-active and evidence-based medical knowledge is integrated in these systems. Statistical analysis, artificial intelligence and machine learning techniques will play a key role in future information systems. Data, information and medical knowledge have to be combined to support decision processes and to manage patient care, but also prevention and patient empowerment. Furthermore the usability of many information systems is far away from user-friendliness or active user support and therefore the challenge is to design user cockpits which are more intuitive and service-orientated.

eHealth Applications

The continuous improvement and extension of the electronic health care record (EHCR), especially in the direction of a personal health record, will be in the center of the future development of eHealth [8]. Patient health records (PHR) are more than a static repository, they combine data and knowledge and software tools, to help patients to become active participants in their own health care process. They serve as a database for patient-specific self care and self monitoring. The central element of eHealth is the EHCR, which includes many different applications and functions. Around these applications there has to be a robust, 24 hours available infrastructure for communication, archiving, identification, authentication and data processing. This system has to be embedded in a framework including legal aspects, defined roles of different users, technical and semantic standards and last but not least health politics for the transformation of the health care system. And for the implementation a national and local eHealth strategy is necessary to guide a systematic implementation.

Worldwide there are already many different applications implemented. We can learn from them and we can improve them because of the availability of more powerful computers and new technologies. The most frequently implemented applications are eMedication, eOrdering, eDocumentation, eScheduling, eLab, eConsulting, home monitoring, portals for consumer information, financial and administrative processes, teleradiology, telepathology, telecardiology, teleconsulting and many other telemedicine applications. In the future eHealth applications must be more flexible and it must be possible to tailor them according to the users' attributes. Applications must be user-friendly and practical. The brilliance of eHealth solutions has to show up in simplicity and not in complicated and sophisticated solutions.

The challenge for MI is to develop eHealth functions and applications which are generic from the research viewpoint but can be customized to the different health care systems in each country.

The Future Development of eHealth

Many years the development of the health care system in most OECD countries was focused on structure quality. In the last years the focus was shifted toward process quality and in the future the focus will be on outcome quality, that means not only efficiency but also effectiveness.

It is not very easy to make a prognosis about eHealth and future trends in patient-centered computing, because of the fast development of this field. It is obvious that there will be a health care paradigm shift from a fragmented to an integrated health care system [9, 10]. Today many health care providers, e.g. hospitals, specialists, ambulatories, nursing homes etc., use information systems but mainly within their organization. From a patient's viewpoint this is a fragmented system. What we need in the future is a patient-centered integrated system, where different healthcare provider teams of specialists cooperate and share information about a patient. The whole relevant information has to be available at the point of care in an optimal presentation.

This fragmentation is also reflected in many health care financing systems and therefore other forms of health care financing systems are necessary in the future. An integrated health care system needs also an integrated health care financing system. This is also a challenge for administrative information systems and for structured documentation, e.g. to build episodes of care.

In the past the main task of the health care system was diagnoses, therapy and rehabilitation. Lower priority was given to prevention or patient empowerment. Health care was mainly the job of professionals and the patient had only a small part or a more or less passive role. In the future prevention, patient empowerment, support of the activities of daily living and support for an increased quality of life and the active role of the patient himself/herself will be important [11]. This new role of citizens respectively patients has to be supported by ICT and the recent developments for ambient assisted living and mHealth (mobile health care) are good examples for this new paradigm. Especially

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monitoring programs need a very high level of privacy.

Today health care is focused mainly on acute care. It has to shift to prevention on the one side and to the management of chronic diseases on the other side. Before coming to the technical aspects the social and ethical consequences of eHealth applications should be considered [12]. There is an ethical and social responsibility for eHealth applications and the following aspects have to be kept in mind:

- First of all, eHealth cannot replace the personal and social contact between people and health care providers. One should be aware of the problem of social isolation due an excessive use of electronic communication.
- eHealth has to take into account the values of the citizens respectively patients, e.g. if monitoring systems are considered.
- Privacy of health-related data is at least in Europe one of the key issues. The different roles and rights for the access to eHealth data for the different health care providers have to be defined and citizen must have control over this access.
- One of the risks of eHealth is the reliability of technical systems and therefore appropriate processes if the systems fail, have to be considered in the implantation strategy.
- Continuity of care also means the integration of health and social care, e.g. also the integration of home health care.
- eHealth should support all stakeholders (citizens, health care providers, health care institutions, financiers, health politics) and try to harmonize their sometimes different expectations and requirements.
- A very big challenge is the usability in general and the usability for handicapped people in special.
  - Especially in health care there is a big problem with terminology. Beside the functionality the appropriate terminology has to be used to avoid the digital divide.
  - With regard to acceptance cultural differences have to be considered.
- And last but not least eHealth has to demonstrate cost effectiveness and improvement in quality.

Table 1 Technical and functional interoperability

1. Standardized communication protocols
   1.1. Open standards for communication and archiving
   1.2. Architecture of archives
   1.3. Architecture of documents
2. Establishing of well structured archives for fast access
   2.1. Indexing of documents for a more efficient retrieval
3. Structuring the content of the relevant documents
4. Identification and authentication
   4.1. Unique and secure identifiers, which can be replaced if they are lost
   4.2. Examination of the validity of biometric identifiers
5. High-performance network infrastructure
   5.1. Risk management strategies
   5.2. Concepts if the network infrastructure breaks down
6. Identification of relevant documents for the electronic health record
7. Supporting clinical trials and research
   7.1. eTrial, electronic capturing of research data
   7.2. Computer-assisted trial design
   7.3. Building clinical research networks
8. Standards for mHealth and telemedicine
   8.1. Standardized interfaces for mobile equipment for home monitoring
   8.2. Devices for ambient-assisted living
   8.3. For communication with virtual hospitals
9. Design of respectively transformation of the current situation into efficient eHealth-supported processes
10. Pro-active decision support systems
    10.1. Provide immediate access to patient information and decision support
    10.2. Capture patient safety information as a by-product of care to design safer care systems

Table 2 Semantic interoperability

1. International multilingual terminologies, ontologies, classification systems
2. Analysis of free text
3. Implementing of archetypes
   3.1. Sharing elements between different information systems
4. Modelling of information
   4.1. Documentation of concepts
5. Documentation standards for biosignals
6. Handling of genetic data
   6.1. Standards for the documentation of data from molecular medicine
   6.2. Personalized medication
   6.3. Molecular imaging

Table 3 Guarantee privacy as appropriate at the current state of art

1. Up-to-date technical and organizational measures for privacy and security
   1.1. Encryption
   1.2. Log file of accesses
2. Establishing of a national auditing system for data protection

Table 4 Legal framework

1. Definition of up-to-date measures for privacy and safety
2. Framework for documentation, communication and archiving
   2.1. Definition of the content and structure of relevant documents

The following lists should just show the direction of future developments in eHealth and are some ideas for an extension of the current functionality of eHealth systems. They are derived from discussions about the development of health care systems, from evaluations of current systems and from studies of different eHealth strategies [13, 14]. From a strategic viewpoint the aims can be summarized as: improving the quality and efficiency of care in an integrated social and health care system based on technical and semantic interoperability and pro-active systems for data, information and knowledge processing. Furthermore national and international aspects with regard to the mobility of patients have to be considered. To meet the future challenges of eHealth and to support the transformation of the health and social care system a lot of

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Table 5 Knowledge presentation, processing and integration into the workflow

1. Standardized presentation of medical knowledge
   1.1. Transformation of scientific literature into computer-processable knowledge
2. Knowledge-based (not memory-based) care decision support
   2.1. Learning systems
3. Evidence-based decision support (not expert systems)
   3.1. Setup and maintenance of medical knowledge base
   3.2. Development of inference engines
4. Assistance for the interpretation of images and bio-signals
   4.1. Using methods of intelligent pattern recognition and machine learning
5. Implementation and integration of evidence-based clinical pathways
   5.1. Standardized presentation of guidelines with Guideline Implementation Format (GLIF) or XML
6. Evaluation of treatment recommendations
7. Models for prognosis of the outcome
   7.1. Setup of database for outcome data
8. Interactive eLearning systems
   8.1. Explanation of complex terms
   8.2. Translation of common phrases into medically valid concepts
   8.3. Interactive animated games for children
9. Access to up-to-date medical knowledge

different functionalities, applications and measures have to be developed. They are described in short by some keywords in ▶Tables 1–13.

Some of these functionalities and applications are already implemented or partially implemented but for many of them a high potential for further improvement exists. Out of this very long list of necessary future developments in MI the key elements can be summarized to interoperability, personalization, patient centering, knowledge management, usability, data processing and last but not least data protection (▶Tables 1–4). Some of these key elements will be explained with respect to their functionality and with regard of possible applications. Furthermore a classification of these activities according to

- online/offline
  - real time/store – forward – respond
- target population
  - citizen/patient/health care providers/administration/financiers/health-politics
- type of activity
- technology used

can be done.

Table 6 Education for health care professionals

1. eLearning for medical students, nurses, students of medical informatics, public health, …
2. Virtual medicine
   2.1. Virtual planning of health care interventions
3. Virtual universities
   3.1. Learning with virtual patients
   3.2. Advanced training, professional development
4. Cybermedicine
   4.1. Simulation of physiological and pathological processes

Knowledge Management

There is a big gap between the knowledge that exists and the knowledge which is available at the point of care [15]. Furthermore the fast continuous development of medical knowledge has to be considered (▶Table 5). Of course at lot of medical knowledge is memory-based present, but this is not always the up-to-date and best knowledge. The dissemination and integration of evidence-based medical knowledge will become one of the most important factors to achieve the best possible outcome, the highest effectiveness. The way how medical knowledge is presented today has to be changed with regard to a standardized terminology, transformed into executable rules and evidence-based knowledge has to be integrated into information systems.

Another aspect of knowledge management is to provide patients with relevant customized, and if necessary simplified health information [16]. The search for this information has to be simplified and it must be possible to integrate data from the patient record into this search. The semantic web technologies will become very important to link information e.g. form patient records with knowledge bases. UMLS or MeSH terms and semantic relationships can be used for browsing and searching. Furthermore the patient has to be actively guided through this search.

A virtual health assistant [17] may become a central tool to assist the individual care process. This virtual agent can have a simple reminder function but it can also search for newest scientific findings or for clinical trials. They should assist patients to have more control over their health.

Decision Support

Decision support systems in health care have a long tradition in isolated systems [19]. The possible benefits to detect medication interaction and incompatibilities are well known. Other systems are supporting the diagnostic process [20]. The challenge of tomorrow is to integrate decision support systems into clinical information systems (▶Table 5). They should act pro-active and produce reminders, warnings, ask questions, analyze trends based on the data of the electronic record and on up-to-date medical knowledge. In the long-term perspective they can be trained by the outcome of their decisions (▶Table 6).

Usability

A strong weakness of many information systems today is the usability and therefore the acceptance of some information systems is low and human-computer interaction has to be improved (▶Table 7). The eHealth industry has to analyze the processes more detailed and must design new processes with regard to the optimal operation of the information systems. Service orientation means active

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Table 7 Usability

Usability
1. eHealth applications have to be self-explaining and intuitive
2. Single sign on to many health care services
2.1. Development of health portals
3. Service-orientated
4. Support of navigation
5. Support of interdisciplinary teamwork
6. Presentation of data, information and knowledge
6.1. Customized presentation
6.1.1. Patient-specific view
6.1.2. Provider-specific view
6.2. Selective retrieval of information
7. Active support of documentation
7.1. Support of classification of diagnoses and procedures
7.2. Reduction of routine reporting
8. Support of patient management
9. Active support of the user
9.1. Citizens, patients
9.2. Health care providers
9.2.1. Support for structured documentation and classification
9.2.2. Alert systems
10. Self-learning systems
10.1. Identification and organization of relevant information
11. Error prevention and error handling
12. Usability for handicapped people
13. eHealth for children and teens
13.1. Animation tools for children
14. Integration of today non-user

support of the user or teams of users for a patient-centered workflow.

It should be possible to customize the view according to individual preferences. The selective retrieval of information according to an individual user profile, e.g. with regard to the speciality of a doctor or to the diagnoses of a patient, will become very important to avoid "information overload".

Information has to be presented in a way that it can be interpreted from a person or a computer. The results of the interpretation process have to be displayed in an appropriate format and it can be shown in different order or grouped in different way [17].

Table 8 Personalization

Personalization
1. Customized patient support
2. Virtual personal health agent
2.1. Personal health-related knowledge finder
2.2. Self-learning of individual priorities
3. Development of interactive systems for patient diaries
3.1. Connected to equipments for home monitoring
4. Filtering of user-relevant information

Personalization

Intelligent approaches have to be implemented to enable more personalized eHealth services delivery [18]. An adaptive user interface should assist a user to customize a search engine according to his needs and interests (▶Table 8). Especially for the self management of people with chronic diseases a personalization of relevant information can become very important. eHealth can also learn a lot from the "Amazon-model", where the information of previous searches is used to find new information.

For the health care provider the relevant information for a certain patient has to be selected out of the possibly huge amount of information. The user profile has to be stored and also continuously improved by a learning system.

Data Processing

There is a huge amount of information already in many information systems and it could be used for scientific purposes as well as for the management of health care providers (▶Tables 9–13). Today a lot of information is stored unstructured as free text. In the future more information has to be stored in a structured way but not as single items. A meta-data model is necessary to show the relations between these items. It is self-evident that all the data used for scientific and other non-patient-related use have to be anonymized or pseudonymized. One of the big chances using these data is outcome research because of the longitudinal structure of the EHCR. Another

Table 9 Support of the transformation process of the health and social care system

Support of the transformation process of the health and social care system
1. Design of respectively transformation into efficient eHealth-supported processes
1.1. Provide immediate access to patient information and decision support
1.2. Capture patient safety information as a by-product of care to design safer care systems
2. Applications for prevention, health promotion, patient empowerment
2.1. Support of consumer health care
3. Integration of health and social care
3.1. Development of documentation standards for social care
3.2. Development of classification systems for social care

Table 10 Support of administrative processes

Support of administrative processes
1. Resources management
1.1. Establishing of data warehouses for medical controlling
2. Online booking, scheduling, notification of appointments
3. Pro-active systems for automatic generation of reminders
4. Extraction of administrative data form medical documentation
5. Support of care, case and disease management models
5.1. Support of multidisciplinary patient-centered cooperation

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Table 11 Financing models with regard to eHealth

1. Financing of episodes of care
1.1. Integrated health care financing models
2. Models for the financing of telemedicine services
3. Financing of the eHealth infrastructure

Table 12 eHealth for developing countries

1. Customization to the special infrastructure
1.1. Use of mobile devices, mHealth
2. Access to knowledge bases
2.1. Support of community health workers
2.2. Telediagnosis
2.3. Teleconsulting
2.4. Distance learning programs
3. Collection of basic data for public health programs
3.1. Health surveillance

Table 13 Processing of the eHealth data for research, management and health politics

1. Institutions for anonymization and pseudonymization
2. Science and research
2.1. Epidemiology
2.1.1. Pharmacoepidemiology
2.2. Health economics
2.3. Health system research
2.4. Development of prevention programs
2.5. Outcome research
3. Support of population health management
3.1. Surveillance of the incidence of diseases
4. Quality assurance
5. Planning and control
6. Pattern recognition
7. Prognostic models
8. Management of health care facilities
9. Evaluation of eHealth activities
9.1. Cost-utility analysis
9.2. Cost-benefit analysis

example is surveillance of the dispersion of diseases because data are collected more or less in time.

Discussion

eHealth should be renamed to iHealth because it is focused on information. Documentation, storage, communication, data processing, identification, authentication, encryption are the technical aspects. But as we have learned from many IT projects the key success factor is the development of the organization and the transformation process. eHealth can learn from other virtual organizations and e's. The benefits of eHealth can only be realized when the processes in the health care system are changed respectively transformed with regard to the support offered by ICT. eHealth is more about understanding people and processes, developing new models of care than about technology. The credibility and value of eHealth lies in its ability to demonstrate positive outcome effects [21, 22].

To manage the high amount of information high-capacity broadband networks and storage and retrieval systems are necessary. They are the basic layers of the eHealth infrastructure.

eHealth has to support and re-establish the doctor-patient relation. eHealth will shift the traditional model of the patient-physician relationship to a patient-health care interface [22]. Patients have to become fully integrated members of their care team. The high potential of eHealth is to optimize the limited time of health care providers and to organize solutions for medical and organizational problems.

The successful further development of eHealth will depend to a high extent on technical and semantic standards, the interoperability and the usability of the systems. And maybe the standards of tomorrow are open standards. Initiatives like the Open eHealth Foundation can boost the further implementation of eHealth [23]. The interoperability of the content in a multilingual environment is one of the biggest challenges in eHealth for the next years and much research has to be done in this field. Semantic interoperability is an inescapable precondition for any kind of data, information and knowledge processing, like decision support, integration of medical knowledge into the workflow, seamless communication within Europe, etc.

The role of the academic research is to identify the demands and functionality of eHealth applications and to develop strategies and concepts for the implementation and transformation of the health care system. eHealth has to merge with public health. And last but not least eHealth has to be evaluated regarding its quality, efficiency, effectiveness and sustainability [24].

eHealth cannot solve all the problems of the health and social care system but it can support the transformation process and help to make the system more efficient, safer, more effective and more patient-centered.

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