Web-based telemedicine systems for home-care: technical issues and experiences

R. Bellazzi a,*, S. Montani a, A. Riva b, M. Stefanelli a

a Dipartimento di Informatica e Sistemistica, Università di Pavia via Ferrata 1, 27100 Pavia, Italy
b Children’s Hospital Informatics Program, Children’s Hospital, Boston, MA, USA

Received 4 October 1999; received in revised form 10 April 2000; accepted 22 May 2000

Abstract

The use of the Web for telemedicine applications seems nowadays a compulsory solution: the Web has become a standardized infrastructure for giving access to sophisticated telemedicine applications from virtually any machine and operating system. Such standardized communication platform guarantees accessibility and usability advantages to both customers and providers (patients and physicians). However, there are several issues that should be discussed in depth, with particular reference to all the applications related to the provision of care at distance, nowadays called telecare applications. In telecare applications the role of the patient becomes central, since he/she is actively involved in the process of managing care and treatments, and since he/she (or his/her families) is responsible for collecting some measurements and related information. In this paper we will discuss the general architectural and technical issues related to the development of Web-based systems for telecare applications, relying on the experience we gained within the telecare project T-IDDM (Telematic Management of Insulin Dependent Diabetes Mellitus), devoted to assist the management and home-monitoring of Type 1 Diabetes Mellitus patients. © 2001 Elsevier Science Ireland Ltd. All rights reserved.

Keywords: World Wide Web; Telemedicine; Telecare

1. Introduction

It is widely recognized that the WorldWide Web has been, in the last few years, one of the main motivations for a wider use of computers in hospitals, and clinical environments in general [1]. As a consequence, although the Web was born as an infrastructure for publishing and retrieving information on the network, its ubiquitous acceptance has pushed software developers to use it to create standardized front-ends in client–server applications. The Web therefore has become the infrastructure for giving access to sophisticated applications from virtually any machine and operating system, thus allowing all users to communicate at distance by relying on a common application server. In the medical field, the distributed nature of telemedicine applications finds
in the Web a standardized technical solution: all information and applications are stored in a logically centralized location that may be distributed over the network in several resource-providing servers. The advantage of using a standardized communication platform is enormous for both customers and providers (patients and physicians), and is progressively resulting in Internet-based telemedicine and teleconsultation services for a number of different pathologies.

While the use of the Web for telemedicine applications seems nowadays a compulsory solution, there are several issues that should be discussed in depth, with particular reference to all the applications related to the provision of care at distance, called telecare applications. In telecare applications the role of the patient become central, since he/she is actively involved in the process of managing care and treatments, and since he/she (or his/her families) is responsible for collecting some measurements and related information. The management of a chronic patient is therefore a collective and cooperative enterprise that may exploit Information Technology (IT) to improve the overall quality of care [2]. The complex network of human and machine relations involved in this process should have strong implications in the design of the Web service. From the technical point of view, it is required that the Web application enables efficient data collection, and this may imply the involvement of applications running on the client and/or an interface with measurement instruments. The communication of personal and treatment data needs to rely on secure software, and the choice between an Internet- or Intranet-based architecture may represent a critical decision, that reflects on the costs and potential dissemination of the resulting service. From the “social” point of view, it must be carefully considered how all the agents involved interact and cooperate, and how the use of IT tools modifies such relationships. Finally it is important to analyze if and how the data exchanged in a telecare system may be progressively transformed in “information” for the systems users and finally in operative “knowledge”. This of course means that the overall service should have, as the final goal, the aim to effectively manage the knowledge necessary to handle the information flow between patients and physicians, and more in general, the overall process of health care.

The authors of this paper have been involved for some years in the telecare project T-IDDM (Telematic Management of Insulin Dependent Diabetes Mellitus), devoted to assist the management and home-monitoring of Type 1 Diabetes Mellitus patients. This project is based on the Web technology and represents an example of an integrated system whose final aim is to assist the entire disease management process. Relying on the experience gained in this project, in this paper we will address the general technological issues related to the development of Web-based systems for telecare applications.

In Section 2, we will point out the general issues underlying Web-based systems, and in Section 3 we will review some current successful applications, following the previously outlined perspectives. In Section 4 we will describe the relevant aspects of the T-IDDM project and in Section 5 we will address some emerging directions; finally in Section 6 we will report some conclusions, envisaging a larger perspective in designing the new generation web-based systems.

2. Web-based telemedicine systems for home care: general issues

As stated in Section 1, there are several issues that should be addressed in the definition of Web-based telemedicine systems for home care. We have grouped these issues into three main categories: architectural and technical issues, comprising data collection and acquisition from measurement instruments; security, privacy and confidentiality; usability and user acceptance. Although interoperability issues are also crucial in Web-based telemedicine applications, they will be not considered in detail here, since they are not specific to home telecare, but belong to a more general problem that standardization bodies are addressing.
2.1. Architectural and technical issues

A variety of software solutions are currently available to provide services over the Web. An increasing number of software vendors have designed Web servers able to access data-bases and computational routines; moreover, servers allowing the definition and customization of complex functionality using CGI scripts, Java-based applications, or general-purpose software languages are available on the market. In other words, the currently available technical solutions are sufficiently sophisticated to allow the development of servers with the functionality required by a general telemedicine service for home care, i.e. the capability of collecting, retrieving and visualizing data and therapeutic information through a secure Web-based access for both patients and physicians. However, it is still under debate what kind of solution should be provided to the final user, with particular reference to the patients’ side, and, consequently, what kind of architecture should be adopted for telecare applications. The questions are of course not trivial, and their answers depend on the particular application at hand and the type of users that are expected. The main issues under this point may be summarized as follows:

- The patients’ terminal. Although the diffusion of the Web is rather high in western countries, the difficulties experienced by technologically unskilled people in the use of computers still pose a barrier to the adoption of Web-based solutions. In several applications, ad hoc-terminals, smart-phones [3] or palmtops [4] have been made available to patients, limiting the access to the Web service to physicians and care providers. More recently, access to the Web from patients’ house has been proposed, through the use of Web-TVs© and Web-phones. The ideal solution is the integration of mobile terminals, such as palmtops or mobile phones for easy data input, with Web-access available also to patients. Clearly, cost-effectiveness aspects should be thoroughly considered before the final system implementation.

- The service provider. A straightforward choice is the provision of the Web-based telemedicine service by the health-care organization. In this case, the telecare service can be implemented relying on an Intranet architecture, in which patients access the service via the Public Switched Telephone Network (PSTN) or ISDN lines, and in which the health care providers may rely on a local area network. This solution has intrinsic advantages in terms of security, confidentiality, and reliability; on the other hand, it limits the system’s accessibility, and it requires the health-care organization to actively manage the system’s hardware and software. A possible alternative setting is one in which the Internet service (e.g. a data-base for home monitoring of certain parameters) is established and managed by a third party, that sells the server’s functionality to both hospitals and patients; in this way, any patient may register for, and have access to, a certain service, and, conversely, any hospital institution may ask the third party service provider for the activation of such service. This solution makes software maintenance easier for the hospital institution, and makes it possible to establish telecare contacts between patients and hospitals in different areas, leading to a sort of globalization of the health-care market. However, several problems remain in terms of security and confidentiality, and the use of interoperability standard is mandatory to maintain the compatibility with legacy systems. Finally, the differences in health-care systems may prevent a true globalization of the services.

- Synchronous and asynchronous services. The health care provider should decide what kind of communication is needed in the particular telecare system under study: while asynchronous systems are necessary for handling data acquisition and communication, in some contexts the use of video-conferencing session may greatly enhance the level of acceptability and patient compliance in the overall system. However, issues related to the quality of such sessions must be considered, in particular when the patient (as in most cases) has access only to low-speed network (Internet/Intranet) connections [5]. Interesting experiences on such kind...
of applications are only recently being reported [6]; in the near future we foresee the publication of studies about benefits and difficulties of using video-conferencing for patients tele-care.

- Data collection and acquisition. One bottleneck in Web-based home monitoring is the need for specialized software interfaced with instruments for data acquisition, which reflects in an increased complexity of the architecture at the client side. A straightforward choice that has been adopted in the past is to avoid the use of the Web for the patient's application, relying on ad hoc software solutions for both data-acquisition and communication. This choice, however, deprives the developers and the users of some of the advantages of the Web environment; problems in the definition of a widely acceptable and standardized user interface, and problems with the software distribution and maintenance may also frequently arise. More recently, the advances in networking applications technology have opened new interesting ways to cope with these problems: it is now possible to enable Java applets or ActiveX controls to access the operating system functionality of the client, using cryptographic certificates to ensure that the software comes from a trusted source (as described in Section 2.2). A feasible solution, that is now becoming the most suitable choice, is to couple a downloadable executable, able to manage data acquisition and instrument interfacing, with a user interface built using Java applets or ActiveX controls, that invokes the local executable. This solution guarantees an improvement in terms of software maintenance, although it requires some skill on part of user to configure the client and manage certificates.

2.2. Security, privacy and confidentiality

One of the most important revolutions brought about by the diffusion of the Internet in recent years is the general availability of strong cryptographic security. Once limited to military and government agencies, cryptographic tools are now widely available, and regulatory changes are eliminating the legal barriers that were still limiting their applicability for general-purpose use. Although motivated mostly by commercial and business applications, this development will probably have the most profound effect on health-care systems, due to the particularly sensitive nature of medical data. More in detail, cryptographic tools can be used for two main purposes, both of which are essential to a properly designed medical application: authentication and encryption.

- Authentication. The first step in setting up a secure communication link between two agents is to assess with certainty the identities of the two agents. This is normally accomplished using a class of cryptographic algorithms called asymmetric ciphers, or, more informally, public key algorithms. To use asymmetric encryption each agent should possess two keys, one of them private, that should be kept as secure as possible, and the second one public. The two keys are generated together and have the property that each one of them can be used to decrypt messages encrypted with the other one. In order to prove its identity to another agent, an agent only needs to encrypt an agreed-upon message using its private key; by decoding the message with the public key, any other agent can verify that the sender of the message is indeed the intended one. In practice, authentication on the Internet is accomplished using certificates, data structures that encapsulate general information about an agent and its public key. Several software packages, both commercial and in the public domain, exist to generate, manipulate and use certificates for authentication purposes.

- Encryption. Even when the identity of the peers in a communication link is verified, the data still needs to be transmitted in encrypted form, in order to prevent a third party from intercepting the data flowing in the network. This is especially important when using the Internet, a network that offers very little protection from this point of view. A multitude of encryption algorithms exists, which differ in strength, speed, and mode of operation; in addition to the above described asymmetric ciphers, symmetric ciphers, that require a single key and are generally faster than the former, can be em-
ployed. In this case, it is necessary for both parties to agree on an encryption algorithm and on a common secret key. This step, that must be performed carefully in order not to compromise the security of the whole system, is usually executed during the initial authentication phase; this is the approach used, for example, by Netscape’s Secure Socket Layer (SSL) protocol. Using SSL, most Web servers and browsers are able to establish secure communication links by verifying each other’s identity using certificates, and by generating a common secret key used to encrypt the communication.

While most medical applications today rely on password-based user authentication, this solution offers very little security in practice, and encryption is still rarely used. On the other hand, we expect that, in the near future, all medical applications will have to incorporate strong forms of security. In this case too, the advantages of developing applications in the Web environment are obvious: the diffusion of software tools and libraries to manage security features, and the widespread acceptance of standards such as SSL or X.509 certificates, will make this process easier both for developers and for end-users. Finally, it is important to note that, while in standard SSL connections only the server is certified, the most recent commercial solutions for security handling require the client to be certified, too. However, for obvious technical reasons, in patients’ tele-care only a portion of users may be expected to exploit such kind of solutions, involving a certificate management at the client side. On the contrary, the use of smart-cards seem more suitable for personal information handling (such as private keys).

2.3. Usability and users’ acceptance and the socio-technical perspective

Testing usability and users’ acceptance is a key issue for a computerized system [7,8], that belongs to the general problem of the design and assessment of telemedicine systems. On this topic, there is a growing consensus in interpreting the design and assessment phases as an iterative process, in which the classical distinctions between analysis, design, implementation and assessment is no more valid [2,9]. The overall picture may be reached only by means of considering the complete “social” network in which the service customers and providers are located [2]. In particular, it is important to assess the implications of the change determined by the introduction of the new system in the environment where it will be used [10]. In the context of a hospital, it is important to analyze what are the relationships among the agents using the system, how the new resource is viewed, and if any “resistance” is clearly present. The user’s acceptance will also depend on external issues, such as the regulations governing hospitals in a certain country, the political and economical aspects concerning health care, and the kind of population being served. Inside the hospital, the organizational structure, the hierarchies and the division of labor may influence the outcome of the usability evaluation study. The implementation and use of a medical information resource can affect the organization by causing changes in decision making, in operations, in the quality of information, in the organizational structure, in the personnel attitudes, in staffing and in costs of operation and information processing.

It is clear that the nature of Web-based application can be helpful in the design and implementation of a service in which system development and evaluation activity continuously merge. The capability of the server to automatically collect process information (e.g. number of accesses, kind of accesses, data transmitted) as well as questionnaire results (electronic questionnaires) may enable a continuous revision of the system, that actively involves the user (patient or physician). To this end, the stake-holder matrix approach, as proposed in this context by [11], seems a valuable solution to define players and factors that are important to assess an IT systems in medicine.

3. State of the art and some current applications

The interest for Telemedicine application, and in particular for the use of Web-based solutions for home care, is demonstrated by the widespread appearance in the literature and on the Internet of
this kind of services. Such uncontrolled growth has forced the scientific associations to provide some general criteria for the development of these systems. In particular, the American Telemedicine Association (ATA) has recently adopted the Tele-homecare Clinical Guidelines, a set of clinical guidelines for the use of telemedicine for home care [12]. Such guidelines are structured following three criteria, addressing patient care, health providers and technology, respectively. The patient criteria includes recommendations for the patient warranty, including privacy, safety and satisfaction issues. The health providers criteria contain guidelines for the organizational settings, including the tele-visit documentation and recording, the staff requirements and the instructions to patients. Finally, the technology criteria includes basic guidelines for the technology choice and maintenance. These criteria are likely to force telecare applications to systematize their approaches, with particular attention to the health-care organizational setting, that in practical cases can turn out to be the most critical issue to be faced.

Most of the system proposed in the literature can be meaningfully analyzed in the light of such guidelines and of the issues outlined in the previous section. However, it is out of the scope of this paper to provide a comprehensive review; on the contrary, we will highlight some experiences that are in some sense representative of the different topics previously mentioned.

- One of the first published Web-based telecare application is represented by the Home Asthma Telemonitoring system [13]. In this application, a patient suffering from asthma is allowed to record the data collected at home with a portable spyrometer on a palmtop; the data are sent to the hospital through the PSTN, and are then made available to authorized user (physician) through the Web. This service has been positively evaluated through a questionnaire. This experience is a typical representative of the first generation of Web-based telecare system, where the patient side is not managed through the Web: the interface with the instrument is realized through specialized software. On the other hand, a careful analysis has been performed in order to decrease the level of technical skills required to the patients and a palmtop has been used for data collection and communication.

- In the field of cardiology, an important experience in the use of Web-based tools is represented by the Heart Care initiative [14,15]. Such initiative is a computerized cardiac recovery service, designed to provide home-care support for patients in the first three months after Cardiac Artery by-pass graft surgery. The access to the service from home is performed by using Web-TVs©. Although results on clinical effectiveness are not still available, some first usability studies have been recently published. In particular, it has been concluded that the Web-TV© is acceptable to patients, that, after a single training session, are able to effectively use the system. It has also been noticed that Web pages may be designed to take into account the limited visualization capabilities of Web-TVs©.

- Another interesting experience of home service is the Baby CareLink system [16], where the families of Very Low Birth Weight infants receive home support, both during newborn hospitalization and during the first week at home. With respect to the standard telecare problems, in this application the emphasis is on the communication between the health care institution and the families, and synchronous (video-conferencing) functionality are coupled with Web pages. Such pages were carefully designed to improve the patients’ acceptance and to manage different information access for several classes of users. There is no intensive data collection at the patient’s home side. The system is currently under evaluation.

- A generational shift in Web-based telecare system is represented by the work reported in [17], where an ECG home monitoring system is completely implemented by means of a Web-based application. Exploiting ActiveX controls and Microsoft certificates, a specialized software for data downloading is driven via the Web at the client side; this solution enables the user to work with a complete, Internet-based, transparent system. Although the system is still...
a prototype, such experience fosters the search for full Web applications for home care, entirely managed by the service provider.

- Another prototype that shows some interesting new features is represented by the DIABNET system [18], designed to assist patients affected by Diabetes Mellitus in their home monitoring. Such system is designed to manage both asynchronous data acquisition and management tasks (Blood Glucose readings from a glucometer), and synchronous communications, such as telephone or video-conferencing sessions. The attempt to couple different styles of information management represents a promising future technical solution for establishing effective home telecare services.

- A number of EU projects funded within the IV framework exploited Web Technologies for home care. The ATTRACT project [19] studied the potential use of Cable Television network infrastructures to define broadband network applications, able to provide low cost interactive health-care services at home. The MOB-CARE project [20] was concerned on the use of mobile technology for home/ambulatory telecare, integrating a large diversity of services. Finally, the SEAHORSE II project [21] dealt with the development of telematics support and information services for people affected by HIV/AIDS and their carers; such support included Web-based tools for information exchange and retrieval.

4. Experiences within the T-IDDM project

The primary authors’ experience in the field of Web-based telemedicine systems is basically represented by the design, implementation and testing of a system for managing diabetic patients, developed in the context of the EU funded T-IDDM project [22]. Work within this project (1996–1999) has been aimed at developing an intelligent telemedicine service able to assist patients affected by Insulin Dependent Diabetes Mellitus (IDDM), providing physicians with decision support tools for improving therapy management according to the best current medical practice. The project goal was to take advantage of the current state of telecommunications technologies and infrastructures in order to: (i) provide patients with an effective insulin treatment, by carefully balancing insulin doses, diet and physical activity, and customizing the therapy on the basis of the individual patient’s features, thus reaching a good glycemic control and helping delay the onset and/or slowing down the progression of chronic complications; (ii) obtain an appropriate level of continuous and intensive care at home, or in a non clinical environments, through telemonitoring and teleconsultation services, taking into account the needs of remote or isolated individuals that are unable to reach frequently the hospital institutions; (iii) allow for a cost-effective monitoring of a large number of patients and for the best exploitation of social and organizational resources, automating data collection and the management of a large set of therapeutic protocols; (iv) support continuing education of patients through teleconsultation.

4.1. T-IDDM architectural and technical issues

The T-IDDM architecture [23] is composed by two main units: a Patient Unit (PU) and a Medical Unit (MU). The PU, running on the patient’s Personal Computer at home, allows for automatic data collection from the commercial instruments for Blood Glucose Level (BGL) measurement via an RS232 interface. Additional information about diet and life style can be typed in by the patient. The monitoring data can be periodically sent to the MU, located at the clinic. Moreover, the PU assists the patients in their self-monitoring activity, suggesting the insulin dosage adjustments on the basis of the BGL value just measured.

The MU includes a set of tools for data visualization, data analysis and decision support, meant to help physicians in the definition of the basal insulin regimen and diet through a periodic evaluation of the patients’ data, with the aim of providing a quicker and more accurate assistance, in addition to normal clinical practice activities. When a new therapy has been prescribed, it can be sent back to the PU. The two modules are arranged in a networked architecture, in which
the telecommunication system, in the current implementations of T-IDDM, may be represented by the Internet or by the PSTN. The units work asynchronously: although periodical communications are required, it is not a priori known when they will take place; the PU thus has a sufficient degree of autonomy to properly handle the different patient management situations.

One of the main requirements for the PU is portability, to allow aid at any place and at any moment. The PU is currently implemented as a PC based software program, written in Delphi™ and based on a Paradox™ database. Different hardware platforms have been considered, including pocket computers, sub-notebooks, pen-based systems and mobile communication devices (i.e. GSM). On the other hand, the MU is a Web-based distributed environment in which several modules cooperate in a transparent way. The core of the system is represented by a Web server written in Common Lisp, called LispWeb [24]. Applications built using LispWeb have full control over the transactions that take place between the server and the Web browser, and at the same time can make calls to powerful functions to generate HTML pages; moreover, LispWeb makes it extremely easy to integrate legacy applications written in Common Lisp, and to make them accessible on the Web. The use of the LispWeb server allows the Web-based application to exploit the full power of a high-level programming language, as well as any number of external services through an extension of the HTTP protocol called STSP. For example, communications with the PU rely on this protocol.

Through LispWeb, the various tools embedded in the MU architecture can perform complex forms of negotiations, thus providing the physician with all the required functionality. The patients’ data are stored in the MU Oracle™ database; data analysis and interpretation are performed by two modules: the Temporal Abstraction Server (written in C) and the Data Analyzer (written in Common Lisp). The details are presented elsewhere [25]. The automated decision support activity implemented by the MU relies on the Therapy Advisor module. This module exploits the cooperation between two tools that implement two different decision support techniques: Case-Based Reasoning (CBR) [26,27] and Rule-Based Reasoning (RBR) [28]. Moreover, by exploiting the negotiation functionality provided within the MU Web-based environment, we have integrated the CBR and the RBR decision support facilities [29], thus implementing a multi-modal reasoning tool.

4.2. T-IDDM security and interoperability

Security and interoperability issues have been considered when developing the T-IDDM prototype. Both the PU and the MU incorporate a password-based authentication system. Moreover, using a combination of single-key and double-key cryptographic algorithms, we were able to turn a simple plain text communication protocol into a secure protocol, in a transparent way: the parties are not aware of the existence of the secure layer of the protocol, and all the functions pertaining to key generation and management are performed automatically by the communication software. In more detail, the project used an extension of the STSP protocol (see previous section) that implements a hybrid security scheme for the T-IDDM system. In this protocol a public key algorithm is used to crypt the session key (in this case, the client’s password). In every session the server generates a new pair of keys (public and private); the client must obtain the public key and crypt its credentials. After the response by the Server, that checks whether the client is authorized, the client and the server can exchange the data, that are encrypted using a symmetric algorithm.

An important extension to the T-IDDM project concerns the ability to communicate patient data and other relevant information (e.g. therapeutic protocols) to other institutions. To this purpose, it was necessary to identify a suitable set of standard coding systems and to use them to encode the knowledge contained in the T-IDDM database. The European Standardization Committee and its Technical Committee (TC 251) [30] perform the coordination and follow up for the development of standards in health-care informatics. Health care messages may be expressed in many different formats such as HL7, ASN.1,
EDIFACT, EUCLIDES or ODA. EDIFACT has been selected in the T-IDDM context because it is preferable to a health-care-specific syntax, that has only a limited local scope. An important application of this work is the generation of EDIFACT messages that corresponds to the “basic information sheet” defined in the DIABCARE Qnet project for the evaluation of the care level of the different diabetes care centers [31].

4.3. The T-IDDM evaluation and users acceptance issues

The T-IDDM project evaluation has taken place in four European validation sites: (1) Policlinico S. Matteo, Pavia, Italy, (2) Hospital San Pau, Barcelona, Spain, (3) University Hospital, Padova, Italy, (4) University Hospital, Helsinki, Finland. Two different technical settings have been exploited, an Intranet solution and an Internet solution. The Intranet solution, adopted in Pavia, is described in Fig. 1; it was locally managed by the health care provider, with patients connecting through modems from home using a PPP link. The MU Web server was installed on a Sun Sparc station located in the Hospital’s Scientific Direction, while the database run on an HP-9000 workstation in the EDP of the Policlinico S. Matteo hospital. The Internet-based service, used in the other sites, kept the server and the database centralized, and enabled authorized patients and physicians to connect to the system, located at the University of Pavia, using the Internet (see Fig. 2). The Internet access and the system software were managed by an external service provider.

The Intranet service evaluation started in June 1998, and involved 6 pediatric patients; the Inter-

Fig. 1. Intranet-based architecture of the T-IDDM project.
The general judgment on the technical verification of the PU was positive for all patients, and the access times were also considered to be good. The usability verification presented more heterogeneous results: while the PU was recognized by all patients to be easy to use and relatively efficient, the help provided by the system was considered acceptable only by three patients. Moreover, a negative judgment was given by one patient on the user interface. Such results, although obtained on a very small number of subjects, suggest that a better compliance could be obtained by designing a PU that is configurable on the individual user’s needs. The relative poor homogeneity of the population involved in the verification and demonstration phase, suggests that some work should be done on the customization of the PU according to different patient categories.

Within the Intranet study, a quite large amount of monitoring data was collected (an average of 901 BGL measurements per patient, in 415 follow-up days), and we were able to make some observations on such information. With respect to clinical practice, that at the Pavia center prescribes a therapy revision every 2 months, the T-IDDM patients’ therapies were revised once a month, on the average. HbA1c, the most important indicator of hyperglycemia, showed an average decrease of 1.23%; however, such decrease was not statistically significant. On the contrary, there was a significant reduction \((p < 0.03)\) of insulin requirement. Such results will be further complemented from the completion of the Intranet study [34], that is still running in some medical centers.

These outcomes, even if preliminary, show the feasibility of a Web-based service for Diabetes management, and seem to substantiate the hypothesis that the use of the T-IDDM system could present an advantage in the management of type 1 diabetic patients. In particular, it could permit to perform a tighter control of the patients’ metabolic situation, in a cost-effective way, without requiring additional visits and personal contacts between patients and physicians. Under this hypothesis, a cost-effectiveness analysis of T-IDDM has been reported in [35]. However, only a randomized trial performed over a homogeneous
population may confirm the potential impact on metabolic control. Finally, also the impact on the hospital organization should be addressed in such evaluation trial, with the purpose of understanding the changes in patients/physicians relationships and in the physicians’ workflow.

5. Future emerging directions

The scene of telecare is rapidly changing, due to the technological improvement and the contemporaneous market challenge that pushes software vendors and service providers to make new solutions available. In our view, two emerging directions will lead such changing process in the next few years: the definition and assessment of Multi-Access services and the study of new home care services based on the so-called “smart home” concept.

5.1. Multi-Access services

The Web, although a widely accepted standard, cannot be considered as the only nor the preferential way for the implementation of telecare services on the patient’s side. The technological gap that still exists between the majority of people and computerized systems hampers the establishment of Web-based telecare services able to scale at the population level. The risk is that this gap, for a certain application, may increase the cost/effectiveness ratio so much to render the services substantially useless in the eyes of public and private investors. A possible way to close the competence gap is to introduce easier forms of patient interaction in the system; simplest one (from the viewpoint of the user) is the telephone. Computer Telephony Interfaces (CTI) may represent the key for interfacing the majority of people with complex systems. When coupled with dedicated solutions for instrument data transmission, CTI can also provide patients with feedback on their care. Several successful CTI applications have been tested in different medical problems, with particular reference to chronic patient’s care [36]. Clearly, CTI alone may limit the applicability of the system, and should be always associated with Web based solutions for data access by the health care providers and patients themselves. This is currently pushing towards the definition of the so-called Multi-Access services, in which a central data-base on the server side is accessed through CTI, through the Web and potentially by means of a variety of other platforms, such as mobile phones, palmtops, Web-TVs© and finally PCs (see, for a first example of Multi-Access service [37]). Such services will be tailored to each users, by customizing the data access modalities, that may dynamically change during time. The frontier is therefore the definition and management of such systems in order to provide 24-h services, to make useful information available to the “right people” in the “right form” at the “right time” [38]. The above mentioned ideas have led to the definition of a project called M²DM, Multi-Access Service for the Management of Diabetes Mellitus [39], funded by the European Commission within the V framework in the IST programme.

5.2. Smart home

The currently available Web-based services have been designed for patients with a limited impairment in their social life; this happens in a large number of chronic diseases, such as Diabetes, Hypertension or Asthma. However, the increasing need of hospital-at-home services, including continuous monitoring of patients with hearth and renal failure and the home monitoring of oncologic patients, implies the use of new technologies for transforming the patients’ home in a so-called “smart home” [40]. In a smart home a home LAN connects medical monitoring devices, therapeutic devices and other sensors and a “body-hub”, that collects and dispatches data from all personal systems (e.g. pacemakers). The LAN is also connected with a Local intelligence unit, able to act as an intelligent interface with the services available outside the home, such as hospital access and Internet connections.Within this system, different technologies will be integrated to provide a complete picture of what is happening to the patient to the health care provider: synchronous and asynchronous services will be available and used when necessary. In this kind of
applications, such as in the Multi-Access systems described above, the Web will be only one of the available technologies. Recently a project called CHRONIC [41] has been funded by the European Commission within the V framework in the IST programme.

6. The need of a knowledge management view

It is well known that the development of Information systems for patient care is a hard task, that counts more failures than successes. Organizational issues, and more generally the socio-technical components, i.e. the complex network of people, roles and technology involved in the patients’ care, are crucial factors that may hamper the use of any (even sophisticated) system.

The development of the new generation Web-based services represents a great opportunity to overcome the limitations of many current systems, whose design is only IT-driven. The standardized nature of the Web may enable to put the designer in a favorable condition, in which the technical solutions may be considered nearly solved, and in which the transformation of the health care organization becomes central. One important step of this transformation should be to exploit IT to manage not only the data provided by instruments, patients and physicians, but also the information associated with this data, in terms of interpretation of the data meaning through contextualization and abstraction. Finally, the information available should be collected and revised, in order to be able to express and maintain the knowledge underlying the health care process [42]. If and only if the IT-based transformation of the health care organizations will be accomplished with a knowledge management perspective, the final result of such transformation will be a learning organization [38]; in this re-active organization the institutional knowledge is applied, and, at the same time, is acquired and maintained, relying on specialized software tools and applications. Such applications should be able to disseminate knowledge in a proper way, by selecting particular data views according to the user’s role and to the access technology used. As a related side effect, the knowledge management process involved should ultimately be able to lead to a progressive elicitation of the knowledge used and updated. This would lead to great gains for all the users of the system: the health care providers will be enabled to exploit more evidence and knowledge in their decision making, while patients will be actively involved in the health care process, by becoming learning managers of their own disease.

The next few years are likely to represent a crucial step in the definition and assessment of new telecare services, in which the merging of technology will help the provision of telemedicine to the majority of citizens. It will be a major task of medical informatics professionals to exploit such new opportunities to help the re-engineering of Health Care Organizations into more value-driven, knowledge-based and cost-effective enterprises.

Acknowledgements

This work is part of the M²DM project (IST-10315) funded by the European Commission. The authors thank the anonymous reviewers for their help in improving the paper quality.

References

http://www.atmeda.org/

http://diabnet.vdirect.com/

http://www.aim.unipv.it

http://www.etho.org

http://www.etho.org

http://www.etho.org

http://www.etho.org

http://www.etho.org