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The Concept of Virtual Medical Center

Branimir RELJIN[1]
Michael STRINTZIS[2]

[1] FACULTY OF ELECTRICAL ENGINEERING, UNIVERSITY OF BELGRADE, BELGRADE, YUGOSLAVIA
[2] INFORMATICS AND TELEMATICS INSTITUTE, CENTER OF RESEARCH AND TECHNOLOGY, THESSALONIKI, GREECE

The paper describes a new concept of telemedicine named a Virtual Medical Center. This concept can be assumed as a further step in telemedicine since it uses all benefits known from 'classic' telemedicine but avoids direct doctor-patient contact. Instead, this concept uses a Virtual Doctor, a sort of a smart software capable to mimic several ordinary procedure known from medical practice. This concept can be efficient in case of chronic diseases. Pro et contra arguments for this concept are exposed in the paper.

KEY WORDS: *Telemedicine; Telemedicine signals; Virtual library; Virtual hospital*

INTRODUCTION

The end of the past millennium was strongly marked by an explosive growth of the whole technology, particularly the electronics, computers and telecommunications, culminating with the Internet. Although the Internet was created as an academic network intended to facilitate the e-mail communication between several dislocated computers into the university campus, the users' requirements and technological solutions and capabilities had changed the early Internet and lead it to live its own life. Nowadays, the Internet permits us the immediate access to an arbitrary point over the globe. A number of different Internet services are in permanent use, as for instance, electronic mail (or e-mail, in short, as the first service offered), e-market, e-banking, e-library, distributed knowledge base, entertainment, virtual shops, virtual office, etc. The Internet has penetrated into all aspects of our activities and changed our way of life. One of the most attractive and helpful service offered by new technologies, including the Internet, is certainly the Telemedicine.

Telemedicine means, literally, 'medicine at a distance'. There are several definitions of telemedicine describing different aspects of this concept. Here we can use the following two definitions:

* Telemedicine is the examination, monitoring and management of patients and the education of patients and medical staff, which allows easy access to expert advice and patient information, irrespective of the location of the patient, medical staff or relevant information stored, or, shortly,

* Telemedicine is the use of electronics, telecommunications and computer technologies with medical expertise to facilitate remote health care delivery.

Address correspondence to:
Branimir Reljin, Faculty of Electrical Engineering, University of Belgrade, Bulevar Kralja Aleksandra 73, 11000 Belgrade, Yugoslavia
E-mail: ereljin@etf.bg.ac.yu

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Telemedicine is not a new concept and it strongly depends on technology. By neglecting primitive ways of telecommunications, like fire or smoke signals, drum signals, etc., some people say that modern telemedicine came about with the invention of the telephone. The famous words of Dr. Alexander Graham Bell, in 1876, 'Come here, Watson, I need you', can be interpreted as the first telemedicine call. Certainly, the telephone was used from the very beginning for different kinds of medical consultations. By improving the telephone the first electrical stethoscope was used in 1906. The invention of X-rays (W. K. Rˆntgen), in 1895, permitted the nondestructive investigation of the human interior, leading to the new field in medicine known as the radiology. For diagnostic purposes the visual information is imperative in almost all cases, hence one needs a device that enables the physician to 'see' the patient. Note that the first transfer of the still image was performed even in far 1907, in France, between Paris and Bordeaux, through Lion, by using telephone lines. The basic principle of that transfer, known as tele-photo, was used almost till today. But, the images formed in this way were very primitive and non-realistic thus inapplicable for telemedical purposes. It was necessary to wait almost a half of a century for the invention of more sophisticated devices, based on the electronics, enabling satisfactorily good quality of images. The electronics era started from the invention of the triode, the first electron vacuum tube capable to amplify the weak electric signals (Lee de Forest), in 1906. During the first half of the century, the electronics was dominated by the vacuum tubes. Since 1948, after the invention of the transistor (W. Shockley, W. Brattain, J. Bardeen), the microelectronics era has started permitting the miniaturization of electronic devices. Since that time the rest of the century was marked strongly by the semiconductor technology. The components and electronic devices become smaller and smaller in size, but greater and greater in function. The first integrated circuit was created in 1958 (R. Noyce, 1958) leading to further miniaturization and microminiaturization of electron devices and equipment.

Nowadays, the sub-micron technology (called also the nanotechnology) is used, enabling a very large scale of integration (VLSI), even a hyper large scale of integration (HLSI), and permitting development of various electronic devices which are used in almost all aspects of our activities and have changed our way of life.

Note that for medical purposes many different sensors and converters of non-electric quantities to electrical signals are invented. Opto-electronic converters and amplifiers, among other applications, permit us to form and transmit moving pictures by using electric signals. Note that the first 'television' (TV) based on the electro-mechanical principle was demonstrated in 1924 (L. Berd). Since the invention of the vacuum tube named the Iconoscop (V. Zvorikin), in 1929, a direct conversion of an optical image to an electric signal is being possible, permitting the 'pure' electronic transfer of moving pictures. Consequently, the first electronically based TV broadcast started in France, in 1932. Nowadays semiconductor sensory devices such as CCD (Charge Coupled Device) and CMOS (Complementary Metal-Oxide-Semiconductor) are used for a direct conversion of an optical image to a digital electric counterpart.

The research and development of telemetry were the early telemedicine efforts undertaken by the USSR and the USA within their space race, in late 1950s. The scientists at the National Aeronautics and Space Administration (NASA) in the USA, as well as in the USSR, demonstrated successfully that physicians on the earth could monitor the physiological functions of an astronaut. They decided to monitor constantly the astronauts' physiological functions, such as blood pressure, respiration, and body temperature. NASA developed a medical support system, which included the diagnosis and the treatment of in-flight medical emergencies as well as a medical delivery system, (Figure 1.).

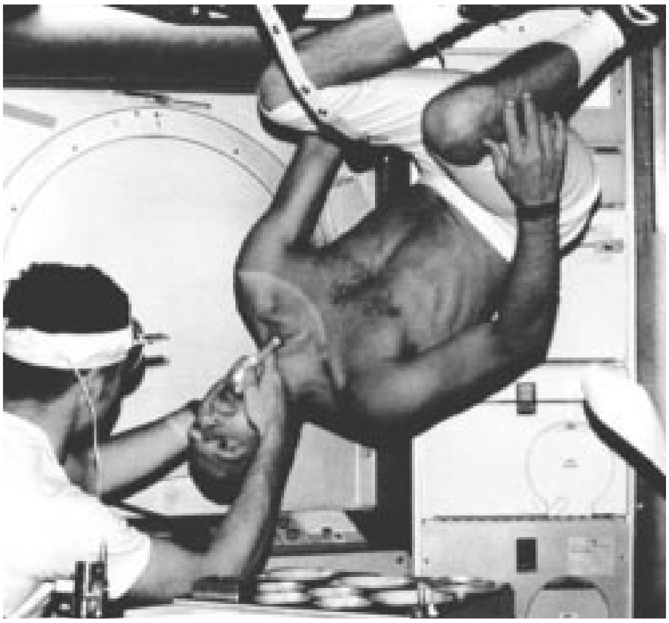

Figure 1. An illustrative example of the telemedicine intervention in the space

Other early telemedicine experiments were based on the use of television. For example, Dr. Cecil Wittson established a patient-physician telemedicine system in 1959 as a part of a telepsychiatry and medical education program in Omaha, Nebraska. Almost at the same time, but independently of him, Dr. Albert Jutras from Montreal, Canada, performed the first teleradiology session between Montreal's Jean-Talon and Hotel Dieu hospitals. A photo of an early telefluoroscopy exam in 1960 is depicted in Figure 2. These experiments demonstrated that it was possible to undertake remote diagnosis by an interactive television. From these beginnings, the interest in telemedicine has continued to grow. Today, telecommunications networks are being developed to transmit information about patients to doctors and vice versa and/or information between doctors, faster than ever before, and virtually, from any location. The same networks can be used to provide access to patient records and medical libraries, to communications among medical specialists, and make available standardized medical information and insurance data more readily. Telemedicine technology is advancing and will continue to do so. Although the more sophisticated technologies such as virtual reality are still expensive, the cost of others is dropping, so that telemedicine is likely to become more affordable to more people, in more regions and countries than ever before.

Figure 2. Telefluoroscopy session performed in Canada in 1960

In this paper the new concept of the telemedicine, named the virtual medical center (VMC), was considered. This concept is based on the 'smart' software called the virtual doctor (VD). The VD communicates with the patient similar to a 'real' doctor, i.e., mimicking the ordinary procedure of a physical examination when the doctor asks the patient about his health condition in order to find characteristic symptoms of the illness necessary for making the diagnosis and suggesting the medical treatment. The paper is organized as follows. In Section II a brief review of the telemedicine is exposed. After some historical observations the details about the telemedicine signals and services are presented, too. In Section III the concept of the VMC is derived and, finally, the advantages and the drawbacks of this concept are discussed in the concluding remarks

TELEMEDICINE BASICS

As noted earlier telemedicine uses telecommunications to deliver health care, often over great distances. The main benefit of TM is to improve the general health condition of the population providing the possibility of cost savings particularly in remote and rural areas. The state of health of the population is a direct determinant of society development. It affects productivity, the potential of children, infant and general mortality, and the allocation of resources within a family, community and nation. The access to better health services reduces poverty and increases productivity. The investment in health is a prerequisite to economic and social progress. Note also that the better quality of life in general, produces the extension of the human life duration. The population of elderly people increases faster than the number of medical personnel. Telemedicine has the potential to improve both the quality of and access to health care regardless of geography and to bypass the shortage of medical staff. In the industrialized world (in the countries of North America, Western Europe, Japan and Australia), there has been a rapidly growing interest in telemedicine. Some of the technologies and experiences of the industrialized countries could help developing countries in their desire to provide improved health care and primary health care in particular. Many developing countries have inadequate health-care and medical services. Developing countries suffer from a shortage of doctors and other health-care professionals. Inadequate infrastructure, such as roads and transport, make it even more difficult to provide health care in remote and rural areas and to transport patients properly. Where clinics and hospitals exist, they are often ill equipped and, especially outside urban areas, beyond the reach of normal communications. Developing countries face various problems in the provision of medical services and health care, including funds, expertise and resources. For such countries telecommunications services have the potential to provide a solution to some of these problems. Telemedicine enables medical and health-care expertise to be accessed from any locations. Certainly, the implementation of telemedicine should be performed carefully and managed well, depending on the particular circumstances. There are many telemedicine applications, some relying on sophisticated and expensive technologies. For instance, telemedicine applications using high-quality videoconference and virtual reality technologies are being developed and demonstrated in the industrialized countries such as the United States and Japan. Such sophisticated and expensive technologies are out of the reach of developing countries. What they need is low cost, sustainable solutions for the delivery of health care, as well as access to appropriate medical expertise. The success of a telemedicine service will depend heavily on which technologies and services are used and on how appropriate they are to particular countries. Clearly what may work in one country may not meet the needs of another country.

Telemedicine encompasses a whole set of practices and involves diverse technologies and applications. It can be characterized by the type of information sent, by the type of services used, and by the type of technologies applied.

Types of telemedicine signals

In telemedicine practice several different types of signals are used, such as text signal, data, audio, and images. A brief characterization of these signals are given in the following text

Text (or, more precisely, the alphanumerical data) is the simplest signal used for describing the patients' personal data and the symptoms of the illness. Having in mind the number of different symbols used (128 according to common ASCII standard) this type of information occupies extremely low memory space. Even for a large patient's documentation (e.g. about 100 pages) electronic record requires less than 3 Mb of uncompressed information. Many hospitals and medical practitioners exchange information such as personal patient's records; records of the outcome of treatments; use e-mail for administrative purposes; employ bulletin boards for up-to-date clinical information; and transmit patient records, referral letters and test results between general practitioners and hospitals.

Data are one dimensional (1D) signals corresponding to the patient's medical record or dynamic information such as vital signs data (heart rate, blood pressure, ECG signal, etc.). Human and animal physiological functions can be monitored from a remote site by using telemetry. One of the first telemetry experiments was conducted at the NASA when physicians on the earth began monitoring the physiological functions of astronauts while they were in space. More recently, briefcase kits for monitoring the vital signs of patients in remote areas and transmitting the data to hospitals or doctors some distance away have been developed; for instance the LifeView Care Station (Eastman Kodak, Rochester, NY), (Figure 3), and CyberCare Electronic House (Cyber-Care Inc., Atlanta, GA), (Figure 4). In Figure 5, a new technology instruments from AMD Company (USA) are depicted; vital signs monitor and the electronic stethoscope.

Figure 3. LifeView Care Station (Eastman Kodak, Rochester, NY)

Audio is also an 1D signal in the low-frequency domain. One of the simplest and earliest telemedicine services is the consultation between health-care workers by telephone. The conventional telephone service (PSTN - Public Switch Telephone Network) is probably the most cost-effective means of facilitating the consultations between remote and rural areas and urban hospitals within a country or with centers of excellence in other countries. The telephone can also be used for consultations between the doctor and the patient. For the diagnosis purposes, as for electronic stethoscope or ultrasound Doppler, a high-quality audio signal is necessary while for videoconferencing standard or even low-quality level are sufficient.

Images are very important for deriving medical diagnosis. They can be in the forms of 2D signals (still images), 3D signals (video signals, i.e., series of successive frames, or static 3D signals - volume signals, voxels), and 4D signals (series of volume signals). Medical images are usually in the forms of still pictures, for example radiographs, or moving pictures, i.e., video. Digitized

Figure 4. CyberCare Electronic House (Cyber-Care Inc., Atlanta, GA)

images are characterized by a large amount of information. For example, a typical radiology session is composed by a large set of images, generally about 4-6 X-ray images of size 2048x2048 pixels (even 4096x4096) and with 12-16 bits per pixel; that means 30-50 Mbytes (or 250-400 Mbits) of uncompressed data per session is needed. A large amount of data requires data compression. Actual compression techniques for still images, as JPEG (Joint Photographers Expert Group) and wavelet permit the compression by factors of 10-100 without significant subjective degradation. For a video signal several standards are used depending on the quality required. For teleconference standards H.261, H.263 or MPEG-1 (Motion Picture Experts Group) are

Figure 5. Two of new equipment for electronic measurement of human's vital functions, offered by the AMD company

used while for better quality, required for telediagnostic purposes, better algorithms are necessary, as MPEG-2. Unfortunately, MPEG-2 needs the bandwidth of 3-15 Mbit/s. Recently adopted (in the end of 1999) MPEG-4 standard permits the video transmission at 300 kbit/s with 25 frames per second and the commercial implementation of video communication at 64 kbit/s is expectable.

Telemedicine image transmission is often aimed for the purposes of teleradiology, which is perhaps the most widely used telemedicine service at present. Radiology is the use of X-rays and other techniques for medical imaging. Teleradiology therefore refers to the transmission of radiological images from one location to another for the purpose of interpretation or consultation. The radiological images of interest are conventional X-ray images, computed tomography (CT) images, magnetic resonance (MR) images, ultrasound (US) images, images from nuclear medicine scans, images from thermography, fluoroscopy and angiography. Other types of images, such as photographic, endoscopic and microscopic images, are also used for diagnostic purposes in medicine. A 3D model can be computed from multiple scans (slices) and the resulting image manipulated using a computer.

Medical databases are complex electronic documents consisting of all signals described above. Many hospitals, clinics and other health institutions around the world use computer systems routinely and have stored their medical records and database electronically. This allows doctors to retrieve information about their patients very quickly. Telemedicine can also be used to keep patient records up to date. Visiting doctors can have an access to patient records and update the data from the distance.

There are many specialized medical databases, especially in the industrialized countries. They generally require access via computer using particular protocols. In some instances access can be free, in others, the user pays for access, for connect time or for both. Medical databases, such as MEDLINE and others, can be accessed via the Internet. MEDLINE is the on-line medical literature retrieval service sponsored by the US National Library of Medicine, a part of the National Institute of Health. This database contains details of over eight million articles in 20 languages.

The Virtual Hospital is a digital health science library created in 1992 at the University of Iowa to help meet the information needs of health care providers and patients by utilizing the Internet. The Virtual Hospital also serves as an information integrator for the University of Iowa Health Sciences Center integrating its digital library information with information from disparate sources such as the Hardin Library for the Health Sciences Healthnet MEDLINE system.

Telemedicine services

In telemedicine practice different services are available. In the following text we will describe in short the main characteristics of them.

Remote access to different medical information is a very useful service for both the medical community and the patients. This sort of tele-library has been in active use in the last decade, as described before (MEDLINE, Virtual Hospital, etc.).

Teleeducation consists of at least three areas: distance education, access to remote information and remote clinical session. In recent years it has become apparent that an efficient and effective health-care infrastructure requires a continuing education of health-care professionals and the public. Education may improve the chances of early detection of disease and reduce the treatment costs. By exploiting telecommunications resources several clinics/universities can be connected offering the opportunity for both training and education. For instance, students living at the rural locality can 'attend' a lecture conducted by a professor at the big teaching hospital. The distance education can involve a small rural teaching hospital linked to the university clinic in a big city. The remote clinical session uses multimedia tools to transmit some medical interventions (for example, a surgery intervention) from one clinic to remote site. This service can facilitate the training of specialists, researchers, doctors, and hospital staff in general.

Telemedicine networks offer the opportunity for consultation between doctors. This telemedical service is known as teleconsultation. The simplest form of teleconsultation uses only the telephone, i.e. a doctor can ask another doctor for clinical information exchange or for a second opinion. Certainly, transmission of images can considerably improve the quality of teleconsultation. Real-time image transfer is possible by using videoconferencing. Teleconsultation can also be done off line, using store-and-forward techniques, such as e-mail or FTP (File Transfer Protocol).

Telemonitoring is the monitoring of the vital signs of patients from a remote site. Several briefcase kits for this purpose have been developed, (Figures 3-4). Telemonitoring is very useful in the emergency medicine as well as in the post-operative treatment, particularly for cardiovascular diseases, or for high-risk pregnancy.

Telecare is in close connection with the telemonitoring. This telemedicine service comprises the health-care, i.e., the use of telecommunications systems to provide a remote assistance in therapy to patients. This service can considerably help elderly people living in their own homes, mental diseases and chronic diseases. Several medical organizations are now evaluating a new generation of interactive tele-health patient monitoring systems. The telecare services (mainly for cardiac diseases) are in permanent use in several countries: the USA, Japan, Italy, Israel, Singapore, China, Spain, etc.

Tele-diagnosis is a diagnosis of a disease made by a remote physician. As in teleconsultation this telemedical service can be performed in real-time (interactive mode) or in off-line mode (store-and-forward application). But, in any case, this type of service needs high quality of transferred images while teleconsultation can be performed even by using less quality images. Note that this kind of service assumes the communications between medical professionals, not between the doctor and the patient.

The telemedicine services vary depending on the necessity and the reality in particular circumstances. For instance, the teleconferencing is based on the interactive digital video, so in order to obtain adequate quality of service (QoS) a high-bandwidth high-speed network (as broadband ISDN or ATM) is necessary. On the contrary, for a store-and-forward application we can use the low-level and low-cost networks as POTS. It must be pointed out that the telemedicine primarily depends on the appropriately organized medical support while the technical background should be as good as possible. But, without physicians an expensive hardware dedicated to telemedicine will be only a useless stock of steel and electronic devices.

IMPLEMENTATION

All the system underlying the network is being implemented using as many Open Source software as possible. In fact, at the present time the basic Operating system chosen for the database server is Linux, while the middle layer is hosted on Sun/Solaris, and on both different software modules have been adopted, as follows:

* Database: the choice is between MySQL, PostGresSQL and Interbase, although currently MySQL is used.
* Web server: Apache v1.3.14
* Dynamic interface: PHP v4.04pl1
* SSL communications: OpenSSL, with the mod_ssl module for Apache
* SSH communication: OpenSSH
* Certification Authority: after considering the acquisition of commercial certificates, we decided not to proceed in that direction, because the level of user authentication usually given by a commercial CA is low, as based only on email verifications. Thus, we started implementing a CA based on the OpenCA effort, which is

in turn based on OpenSSL, Perl and Apache.
Part of the work is still ongoing, thus not all the modules are yet available.
In particular, the choice for MySQL (faster than others) is being reconsidered, because it does not allow a clear transaction management, where more than one database modification is made, while PostGResSQL allows also this.

VIRTUAL MEDICAL CENTER

In the previous section a basic telemedicine services are described. This 'classic' telemedicine comprises humans on both telecommunications sides: the medical staff from the central (hospital) side and the patient and/or medical staff from the other (remote) side. But, by analyzing ordinary medical interventions it can be concluded that in many cases the patients are forced to come to the medical center/hospital only for routine examinations or to receive some medical information or medical advice. Having in mind these facts we suggest a new concept in telemedical care that we can name as a Virtual Medical Center (VMC). The crucial point in this concept is that it uses the virtual doctor (VD) - a sort of the 'smart' software - on the central side instead of the 'real' doctor(s).
The concept of the virtual medical center (VMC) can be subdivided into several categories as follows:
- the virtual medical library (VML),
- the virtual tele-consultancy (VTC),
- the virtual tele-health (VTH), and
- the virtual tele-ambulance (VTA).

Virtual medical library

The lowest level of the VMC is a virtual medical library (VML). The healthcare providers are in constant need of current and accurate medical information that can help them take better care of their patients. Similarly, the patients are in constant need of current, accurate medical information in order to help them to live healthier lives and take better care of themselves when ill. Certainly, such an information is available in print form in libraries but these libraries are usually far from their work or home, and the barriers to accessing the information are quite high. Also, the patients are not usually educated in medicine and cannot understand well all medical terms and/or do not know in which book they can find the answers to their health problems. This leads to a situation of both medical providers and patients often being information poor when making healthcare decisions.
After recognizing this problem and after accepting new technologies a group of researchers from the Department of Radiology and from the Electric Differential Multimedia Laboratory, University of Iowa College of Medicine (the USA), conducted by Teresa Choi, founded the digital health science library known as the Virtual Hospital (VH), in 1992. The VH is a registered trademark of the University of Iowa and is registered in the United States, Australia and Japan.
The VH serves primarily as a digital library for medical and health sciences but also serves as a usable tool for continuing education for academic and non-academic population. It currently contains hundreds of healthcare books and booklets stored as Hypertext Markup Language (HTML) files. These books and booklets range from general references, such as the University of Iowa Family Practice Handbook, to specialized references such as a Guide to Tourette Syndrome. Approximately 50% of the content is meant primarily for medical providers and the rest is addressed primarily to patients. Peer review boards are being established in each clinical department to review the information stored in Virtual Hospital. These files are organized and distributed using the Netscape Communication Server (Netscape, Mountain View, CA). All information on the VH is indexed using the Glimpse search engine (University of Arizona, Tucson, AZ), so the entire site is free-text searchable. The information in the VH is distributed across the Internet to patrons around the world who are equipped with a www browser. Currently users can have the access to VH content at the sites located in the USA, Australia, Japan and Taiwan, and it is expected to establish mirror sites in Europe, South America and East Asia. Each mirror site is an exact duplicate of the VH site in Iowa and is updated on a daily basis.
A similar concept as the VH one is the VML and it will be the first step in establishing the VMC. Note that it is very important to infer that all audio and textual information in VMC services must be derived in the native language and by using ordinary words. Namely, the main part of population is not familiar with the specific and scientific medical vocabulary and can communicate and understand mainly ordinary words. Certainly, the right and precise medical terms should be used in parallel with the common terms, particularly when forming the medical documentation.

Virtual tele-consultancy

The second level of the VMC could be a medical tele-consultancy (VTC). This kind of telemedical service is dedicated primarily to the patients suffering from chronic diseases as cardiac, diabetic and similar, as well as to the postoperative care of patients. Such patients, particularly elderly people, staying at home and probably alone, can suffer from many subjective symptoms of being weak, scared and helpless. An appropriate medical advice can help a patient and make him worry-free.
The VTC service includes a concept of the virtual doctor (VD) - special 'smart' software capable to perform an accurate medical advice through the 'conversation' with the patient. Namely, after connecting to the VMC, via wire or wireless network, the patient asks a VD for the medical advice. A VD is created in such a way

to simulate an ordinary procedure in the ambulance based on the conversation between the patient and the physician. Through an interactive procedure a remote patient sends relevant information to the VD facilitating the formulation and derivation of the medical advice. For instance, the patient describes his health symptoms (objective signs such as the pulse rate, the blood pressure; or subjective ones, as the vertigo, the weakness, the pressure on the breath, etc.) and gives the information of his therapy as which pills and which doses are used. After that the VD derives the medical advice. In many cases the patient's symptoms are only of the subjective nature without any physiology malfunctions. Then the adequate and at right time given medical advice helps the patient permitting him to stay at home and continue his activities.

The VD software used in the VTC concept is more sophisticated than the software for searching data in the VML concept. A very delicate procedure in forming the VD questions predicting possible patient's answers must be created in order to facilitate the formulation of the medical advice. A sort of the artificial intelligence should be incorporated into the software of the VD. As noted earlier, for chronic diseases this service could be a very effective and helpful medical tool. Certainly, in the case when the patient is not quite assured that the advice is adequate and/or when the clear advice cannot be performed, the 'real' doctor can be included in the procedure giving the final diagnosis or suggesting further examinations.

Virtual tele-health

The higher level of the VMC is the virtual tele-health (VTH). This medical service is primarily dedicated to chronic patients, too. The patient's relevant data (personal data and medical records: pulse rate, blood pressure, electrocardiac traces, cardiac sounds, etc.) are stored in the VMC server in the form of a personal electronic medical record. The patient can send his actual medical data to the VMC by using standard computer equipment and telephone lines or by using specially designed and dedicated hardware (as the tele-holter, tele-ECG) with a wireless connection to the VMC. As noted earlier the equipment usually includes a videoconferencing system, a remote stethoscope, blood pressure cuff, a digital thermometer, finger pulse meter and oxymeter, (Figures 3-4). There is no keyboard or mouse because elderly people cannot use them. As noted earlier a sort of tele-care exists in several countries, where rent-a-health service is offered to patients. Medical service is available 24-hour a day: physicians/nurses permanently observe patients' data and give a medical advice, even an emergency intervention, if necessary. The concept of virtual tele-health as a part of the VMC is slightly different from the 'classic' tele-care service described above because it assumes an automatically derived medical advice or the suggestion for the therapy. Only in case of emergency the VD call the 'real' medical staff for help.

Virtual tele-ambulance

Finally, the highest level of the VMC concept is be the virtual tele-ambulance (VTA). This telemedical service operates similar to the VTH but now the virtual doctor software is intended to perform even a medical diagnosis instead of the medical advice alone. This service assumes that the patient is absolutely anonymous and unknown for the VD. The patient passes the whole ordinary medical procedure usually performed in the ambulance. First he gives his personal data and then he describes the symptoms of his diseases. After an interactive communication and correspondence patient-VD the virtual doctor software should derive a diagnosis. In case of ambiguous and doubtful diagnosis the VD calls a real doctor(s) for the final decision. This type of telemedical service could be very effective for rural and isolated areas as well as in cases of emergency: in traffic accidents, on the battlefield, in regions of severe flooding or in cases when it is dangerous or difficult to move and to transport the patient.

CONCLUSION

The explosive growth of the technology in the last decade permits us to create different devices and services that, up to recently, were known only from the science fiction literature. One of such new services is definitely a telemedicine. The main goal and benefits of TM is to break barriers between the developed centers and the rural areas permitting high-level medical services in all places around the globe. A sort of TM called the virtual medical center is described in this paper. As distinguished from other TM services assuming the contact medical-medical or patient-medical the VMC concept is based on the contact patient-computer. Except for the lowest-level of the VMC - the medical tele-library such as MEDLINE or Virtual Hospital - the core of the VMC concept is based on the virtual doctor (VD). The virtual doctor is a smart software mimicking the routine procedure in the medical center. By applying the interactive procedure: the 'conversation' between the patient and the VD, the VD performs an adequate medical advice or even a medical diagnosis.

The benefits of the VMC are those offered by telemedicine in general: the patients are not forced to visit a 'real' ambulance/hospital since they can receive relevant medical information/advice/diagnosis staying in their homes and just in time when they actually need such information/advice/diagnosis. In this way the overall medical costs can drastically be reduced for instance, savings from reduced travel costs of patients and of specialists engaged in consultation, reduced expenses for accompanied persons, savings on hospital accommodation of patients, savings on hospital processing costs of patients, reducing waiting time for consultation and the second opinion, faster diagnosis and treatment, etc. Moreover, the VMC concept improves the total benefits known from telemedicine. This concept can make possible an automatically performed medical advice independent of the time and without the necessity of permanent (24-hours a day) duty/call service in the central office. Only in case of emergency the VD calls the real doctor for help.

The drawback of the VMC concept is that this service, being web oriented, needs the high-bandwidth high-speed network easy accessible and secure, confidential and privacy protected data transfer. Also, if the personal computer is used as a communication device between the patient and the VD then the patient must be skilled to use the PC. However, the more or less automated special hardware (voice driven devices, mobile phones with embedded sensors, etc.) can be implemented.

The main drawback of the VMC concept definitely is the VD software. But, it is also the main challenge of this concept. This software has to be very carefully developed since it must be capable to derive an accurate and clear medical advice and must be absolutely safe for the patient. For establishing such a software a number of specialists, physicians and engineers should be incorporated in the researching team. Moreover, the software has to be tested very carefully before its application in practice. For chronic patients the VMC could be very usable and it is expected that such a telemedical service can be derived.

Some other non-technical problems, such as different ethical and juridical problems, financing, responsibility toward the patient, etc., were not considered in this paper.

REFERENCES

1. Wright D (rapporteur). Telemedicine and developing countries, A report of study group 2 of the ITU development sector, ITU-D Study Group 2, Question 6, Geneva, Dec. 1997.
2. Hindus L. The tele-health model: saving lives, time and money - with imaging. Advanced Imaging, Nov. 2000.
3. Rosen E. Embracing mobile personal video. Telemedicine Today 1999:14-6.
4. Swartz D. Remote access: The last mile is getting shorter. Telemedicine Today 1999: 27-30.
5. Reljin B, Reljin I. Telemedicine in multimedia environment. In: Spasic P, Milosavljevic I, Jancic-Zguricas M, Editors. Textbook Telemedicine. Belgrade: Academy of Medical Sciences of Serbian Medical Association; 2000. p. 22-107.