# Digital medicine in the virtual hospital of the future

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**Abstract.** Provision of global healthcare requires global interoperability of medical services. Therefore, the creation of a Virtual Euro-Mediterranean Hospital for a real integration is proposed. Pre-operative planning, intra-operative navigation and minimally-invasive surgery require a digital and virtual environment supporting the perception of the physician. An integrated satellite-internet platform allows for e-Learning, real-time telemedicine and medical assistance. Due to the distributed character of the virtual hospital the implementation of Grid-enabled technologies and services becomes important.

*Keywords: real-time telemedicine, satellite-based networks, health grid*

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## 1. Introduction

Telemedicine aims at equal access to medical expertise irrespective of the geographical location of the person in need; it promises equally good healthcare at any time from any location: best healthcare for everyone, anytime, anywhere. New developments in Information and Communication Technologies (ICT) have enabled the transmission of medical images in sufficiently high quality to allow for telediagnosis. At the same time, however, these innovative developments in ICT over the last decade bear the risk of creating and amplifying a digital divide in the world, creating a disparity between the North and the South of the Mediterranean. The digital divide in the field of health care has a direct impact in the daily life of the citizens and on their quality of life.

In recent years, different institutions have launched several Euro-Mediterranean telemedicine projects (amongst others the successful EMISPHER project [1]). All these projects have demonstrated how the digital divide is only part of a more complex problem: the need for integration. Therefore, provision of the same advanced technologies to all states in Europe and its neighbouring regions, should be the final goal to contribute to better integration, bridging the digital divide and thus reducing the disparity in quality of life.

Based on successful experiences in the implementation of previous telemedicine projects, an open Euro-Mediterranean consortium proposes the Virtual Euro-Mediterranean Hospital (VEMH) initiative. VEMH aims to facilitate and accelerate the interconnection and interoperability of the various services being developed (by different organisations at different sites) through real integration. This integration must take into account the social, human and cultural dimensions and strive towards common approaches but open and respectful of cultural differences: multi-lateral cooperation instead of aid.

## 2. Methods

The EU is committed to realise by 2008 a number of steps forward in the area of e-Health: electronic health records, electronic health insurance cards, Europe-wide patient identifiers, interoperability of the various cards, medical e-Learning for health

professionals, harmonisation of reimbursement and liability issues, as well as a European public health portal for citizens.

For the realization of global healthcare dedicated telemedicine and e-Health services are needed 24 hours per day, 7 days per week (24/7). These services should meet high standards for reliability and quality of service (QoS). Furthermore, open-source and open-standard solutions are essential for interoperability and integration of the various services. Also, gateways to other communication networks should be created.

The implementation of interactive remote control of medical devices will enhance telediagnosis. Consequently, the medical workflow and decision-making tree has to be re-evaluated and new management tools for global virtual alliances have to be introduced. Mental, intellectual and educational e-services for citizens shall be created [2-3].

## 3. Results

Pre-operative planning, navigation and robotics offer advantages in minimally-invasive surgery by increasing the precision of the intervention and by shortening the recovery time of the patient. As minimally-invasive medicine is image guided it requires an adequate fully digitized environment for optimized usage in clinical routine. Navigated instruments support surgical procedures in various disciplines such as neurosurgery, craniofacial or liver surgery, etc.

All these areas produce an information flood. To deal with such an amount of information, personalized avatars which represent the user virtually in an online community of medical information systems and multi perception for multi media performance in virtual reality environments (visualisation of virtual 3-D objects, full navigation, haptic simulation, etc.) are needed (Fig. 1). It is assumed that multi-modal stimulation in virtual environments raises the experience of presence perceived by the user. Thus, a multimedia and multimodal data display supports perception of the user effectively.

Fig. 1. Surgical Table for operation planning, simulation and training of surgical procedures. Two users can simultaneously observe tracked, stereoscopic views of virtual objects and work interactively (Integration of haptic feedback is in progress).

Information and Communication Technologies (ICT) contribute to digital radiology, digital pathology, telemedicine and navigation and simulation. New developments in ICT have enabled the transmission of medical images (both still images and live video sequences) in a sufficiently high quality to allow for a reliable diagnosis to be formulated by the expert at the receiving site. Real-time telemedicine refers to those applications that involve live transmission of medical data and concomitant live teleconsultation by the remote expert. Successful real-time telemedicine applications exhibit several key factors such as sufficiently high communication bandwidth that is also economically affordable, as well as intelligent data compression modules that allow for drastic reduction of the required bandwidth. In radiology the use of digital, filmless radiology information systems is now standard. For digital pathology a digital virtual microscope must scan the slides at the highest possible magnification and generate images on a PACS server. Image sizes are still large but the vast progression in data storage allows managing this level of data. The system's advanced functionality is likely to enable introduction of digital pathology in routine diagnostic work in near future. However, the promise of telemedicine to provide equal access to medical expertise irrespective of the geographical location can only be met when not merely the patient's data are transferred but rather a telepresence is created bringing patient and remote expert together using ICT. Besides general interactivity between the two sites features like telehaptic, telesensation and remote control of medical devices (e.g. telerobotics) are prerequisite for a real telepresence (Fig. 2).


Fig. 2. MEDASHIP telesonography demonstrator. The expert (bottom right) can diagnose the patient (bottom left) from the US-images transmitted in real-time (top left). The expert can also remotely control the ultrasound (US) head (bottom left) (work in progress).

For treatment according to verifiable guidelines according to the concept of evidence-based medicine an optimization of the clinical workflow is necessary. Workflow management will specify the technical realisation of medical sequences of operations. Here the integration of the different modalities (imaging, medication, OP-report, etc) into a centralized electronic patient record is needed. The electronic patient record has

the potential to improve the communication in health care and consequently the quality of treatment and to save a lot of money.

To integrate all these concepts the Virtual Euro-Mediterranean Hospital (VEMH) will provide a heterogeneous integrated platform consisting of a satellite link, such as in the EMISPHER project (2 Mbit/s bandwidth, mesh topology), and a terrestrial link.

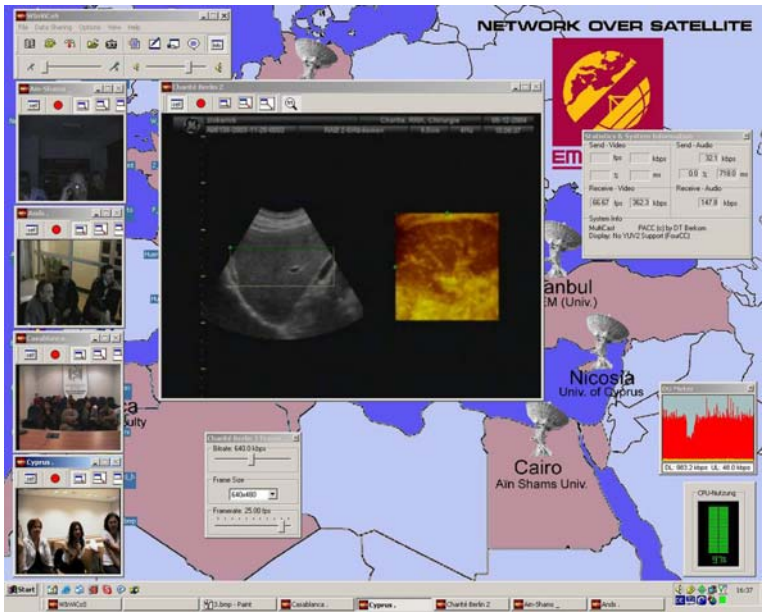


Fig. 3. e-Learning session with transmission of live ultrasound video streams from Charité (Berlin) to Ain Shams University (Cairo), Agence Nationale de Documentation de la Sante (Algiers), Faculte de Medecine et de Pharmacie (Casablanca) and University of Cyprus (Nicosia)


Fig. 4. Interactive multipoint radiological tele-consultation (Charité (Berlin), Faculte de Medecine et de Pharmacie (Casablanca), Istanbul Medical Faculty)

Services offered by the VEMH will include a Virtual Medical University to which the leading medical centers provide pedagogical material for synchronous and asynchronous e-Learning in their medical specialities (Fig. 3). Real-time telemedicine will offer second opinion, telementoring, teleteaching and optimization of the learning curve (Fig. 4). Medical assistance will improve the medical care for tourists, thus stimulating tourism.

An additional key feature of the VEMH is its fellowship programmes for the training of young medical doctors, which allow to develop and to gain experience in a multicultural and multidisciplinary environment. This will facilitate the creation of a new generation of physicians who are able to understand and work with different needs and cultures.

Due to the distributed character of the VEMH, data, computing resources as well as the need for these are distributed over many sites in the Virtual Hospital. Therefore, Grid infrastructures and services become inevitable for successful deployment of services like acquisition and processing of medical images (3D patient models), data storage, archiving and retrieval, data mining (especially for evidence-based medicine) [4-5]. In order to achieve this, conventional Grid technology has to be expanded to cover not only local computing resources but to a dimension of organisation-spanning integrated networks.

Nevertheless, it is crucial that the methodologies for the VEMH are medical-needs-driven instead of technology-driven. They provide new management tools for virtual medical communities and allow management of clinical outcomes for improved implementation of evidence-based medicine. By the integration of different telemedical solutions in one platform many different medical services shall be supported. Adequate data security procedures will be implemented to assure patients' privacy. Each service will be evaluated according to a cost-benefit and a cost-effectiveness analysis.

## 4. Conclusion

VEMH will foster cross-Mediterranean cooperation between the leading medical centers of the participating countries by establishing a permanent medical and scientific link. Through the deployment and operation of an integrated interactive satellite-internet communication platform, VEMH will provide for medical professionals in the whole Euro-Mediterranean area access to the required quality of medical service depending on the individual needs of each of the partner. For the successful deployment of the various medical services in the VEMH the development and implementation of Health Grid technologies and services appears crucial. The applications in the area of e-Learning, real-time telemedicine and improved medical assistance contribute to an improved health care in the Euro-Mediterranean area and build the basis for the introduction of evidence-based medicine.

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