The Evolution of Personal Health Systems (Invited Paper)

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***Abstract*— Personal Health Systems (PHS) represent a disruptive vision, changing the way healthcare is delivered, extending it out of the hospital, bringing it to people's homes and embedding it into their lives. A major aim of PHS is to help individuals assume stronger engagement and more responsibility in looking after and managing their own health. In parallel, PHS enable health professionals to have a more comprehensive picture of their patient's health status, by collecting and making available health monitoring data as patients carry on with their daily activities in their ordinary living and working environments. This article describes the evolution of PHS, the current achievements and outlines possible directions of future activities in this domain.**

I. Introduction

For almost twenty years now, the European Commission has been supporting research and deployment activities for the application of Information and Communication Technologies (ICT) in health – also known as eHealth. The initial efforts focused on the development of networks and tools to assist healthcare professionals. During most of the 1990s, the main emphasis was on supporting the continuity of care through development of electronic health records, integrated regional health networks and platforms for telemedicine services that enabled homecare and provision of care at the point of need. In the late 1990s, the focus shifted towards a new vision of "person-centric" healthcare, through support to the so-called Personal Health Systems (PHS). The central concept in PHS is the placement of the patient or healthy individual as an "active node" in the existing national or regional health information network, thus making him/her an active participant in the healthcare process.

II. Background

Within the concept described above, PHS aim to enhance the education of individuals on health matters, enable them to assume more responsibility in managing their own health, improve the interaction between patients and doctors and offer health professionals the kind of monitoring and diagnostic data which can assist them in making more accurate decisions and offer more effective care to their patients.

PHS present a new generation of disruptive eHealth tools and systems, which promise to offer high quality, personalised care at the point of need with better use of the available healthcare resources. PHS are realised by the integration of various components and technologies (like biomedical sensors, implants, algorithms for signal processing and knowledge extraction, user interfaces, mobile and wireless communications) into wearable, implantable or portable systems used by the patient or healthy individual. Such systems are coupled with telemedicine platforms to provide personalised health services, like remote health status monitoring and disease management, adapted to the circumstances of the individual user and available at anytime and any location beyond the traditional hospital environment. In fact, PHS are seen as key enablers of ubiquitous personalised care, facilitating continuity of care in terms of time and space. They are also important tools for supporting the shift to preventive care, not only by enabling early diagnosis of conditions through continuous monitoring, but also by empowering individuals to manage their own health status and maintain good health.

As presented in a recent workshop organised by the European Commission [1], the operation of PHS involves three main functions:

a) Acquisition of data related to an individual's health status, by means of biosensors and monitoring devices that measure e.g. vital signs and biochemical analytes.

b) Processing and analysis of the acquired data to identify clinically relevant and useful information for diagnosis, management or treatment of a disease. Such data processing can take place in two steps: firstly at the site of acquisition using e.g. software embedded in on-body electronics; and secondly at medical centres where data repositories and more powerful computing facilities are available.

c) Communication of health status data and medical information between various actors: from the individual user to a doctor or a medical centre; from the medical centre which analyses the acquired data to a doctor or hospital; from the doctor or the medical centre back to the individual user (e.g. in the form of adjusted treatment); or from a wearable system itself back to the individual user, e.g. in the form of personalised advice and guidance.

It must be noted that the three main functions described above are interconnected and cannot be seen in isolation. The concept behind PHS is a holistic one, and as such the links between these main functions are of extremely high importance, as far as the provision of healthcare services is concerned.

III. Current Achievements

For the last 10 years approximately, considerable amount of effort has been devoted to research and development of PHS. The industry, national funding authorities and the European Commission have supported the evolution of this domain.

The earliest phases of PHS development can be seen as those employing portable devices and telemedicine services to support homecare. Monitoring equipment like ECG event recorders and blood glucose monitors were used at patients' homes and connected to medical call centres via the telephone networks, transmitting in this way patients' health status data to these centres, which in turn offered medical response and guidance [2].

A further development was the introduction of interactive TV platforms to provide remote telecare services for chronically ill people at home [3]. Such systems facilitate the doctor-patient interaction via easy to use interfaces, while at the same time they can support education of patients, tailored to their health condition (e.g. through educational videos).

Within the Fifth Framework Programme for Research and Technological Development (FP5, 1998-2002) of the European Commission, research projects started exploring how ICT could support the delivery of healthcare at the point of need (anytime, anywhere) and how to help promotion of good health and prevention of diseases. To this end, several projects placed emphasis on the development of components (like wearable devices and wireless body sensors), communications infrastructure and other technologies like microsystems, data processing and decision support for personal health monitoring. The momentum has been sustained during FP6 (2002-2006), in the early phase of FP7 (2007) and in other Commission programmes like eTen. In these latter programmes, the majority of the PHS activities focused more on the development of integrated systems and personalised services that can ensure the continuity of care.

Several research projects succeeded in producing and validating prototype systems ([4]-[9]) such as intelligent wrist-worn devices, body sensor networks and clothes with embedded biosensors. These types of systems are designed to be used by the individual person during their ordinary daily activities. They measure vital signs (like ECG, heart rate and respiratory rate), link to medical centres, issue alarms and facilitate the provision of medical feedback to the individual user. The majority of the work that has been carried out so far on PHS has addressed the monitoring of physiological functions and physical activity as well as functional stimulation.

Through such research efforts and small scale validation studies on e.g., cardiovascular and respiratory diseases, first evidence has arisen that PHS bring benefits to the individuals who use them and to the healthcare systems alike. The benefits are both clinical and economic, and are seen in the form of reduced hospital admissions and hospitalisation days, as well as cost savings through early discharge from hospitals and remote monitoring and disease management [10]. A recent study [11] across nearly 1000 homecare agencies in the United States indicated significant benefits of telehealth applications for homecare. More than 76% of the agencies reported reductions in unplanned hospitalisations and in emergency room visits, while more than 71% of the agencies reported improved patient satisfaction from telehealth services. PHS can thus represent a fundamental advance in the delivery of healthcare services, with potentially substantial savings on healthcare costs at the same time.

IV. Future Directions

The above examples describe what can be seen as “first generations” of PHS. These are now reaching a certain level of technical maturity and are seeking opportunities for deployment and implementation in healthcare practice. The industry is becoming particularly interested in PHS applications, especially those related to remote management of chronic diseases. Collaboration among industrial stakeholders is becoming stronger in an attempt to overcome certain technological barriers like the communication and semantic interoperability among monitoring devices, hospital information systems and electronic health records (e.g. [12], [13]).

Many General Practitioners (GPs) in Europe use nowadays PCs, electronic health networks and other eHealth tools like decision support software for diagnosis and prescription routinely in their daily practice. Despite this, less than 4% of the GPs in 29 European counties make use of eHealth tools to provide telemonitoring to home patients [14]. There is thus large margin for growth in this application domain and, indeed, there are many expectations that the market of remote care will grow fast in the coming years.

Efforts to deploy the first PHS generations are certainly going to be an area of future activity in this domain. However, the deployment of PHS faces many difficulties, the most important of which are no longer technological. PHS are highly disruptive, as they break away from the manner with which healthcare is traditionally delivered. The introduction of PHS in healthcare practice requires significant changes at system level. Consequently, organisational changes, reimbursement, legal framework, liability and cross-border provision of services are now the major issues to overcome in order to facilitate wide deployment of PHS [15]. Political support is indispensable in this respect. To gain this support though, strong, large-scale evidence about the benefits of PHS is required, together with clear demonstration of the existence of favourable conditions for implementing the necessary organisational changes that integrate PHS in healthcare practice. The European Commission has recently launched the Lead Market Initiative which covers among others the domain of eHealth [16]. PHS deployment could well benefit from political initiatives like this.

A second area of activity in the PHS domain is research and development towards new generations of PHS, targeted also to new applications. The European Commission is currently funding a roadmap project whose objective is to identify new research directions for PHS in the coming years [17]. A recent event has also elaborated on new PHS generations [1].

Mental disorders can be an example of promising application area for PHS, considering their rising prevalence. The development of PHS for mental health has experienced up until now less systematic effort in comparison with e.g. the area of cardiovascular diseases. There are several challenges pertaining to the application of ICT for prevention, management and treatment of mental disorders. In this respect, strong links and interdisciplinary collaboration with neurosciences are key elements.

Another potential application area is related to diseases like renal or liver failure, where minimally invasive PHS could be developed to overcome degraded functionality of body organs. Reaping the advances arising from the convergence of ICT, bio-, nano- and material technologies, new types of small-sized wearable artificial organs would have tremendous impact on the quality of life of patients, considering in particular the opportunities for developing artificial organs tailored to an individual's needs.

More research can also be envisaged for PHS solutions that can help prevent the onset of diseases. Some work involving the application of ICT for prevention of diseases has taken place in the past, but there are not many examples of successful application of disease prevention. There are difficulties in demonstrating that prevention has indeed concrete benefits in terms of medical outcomes, as it requires large studies of long duration to establish the evidence that the occurrence of a disease has been prevented. Related to this, is the uncertainty in the industrial community of what business models can be conceived and applied for preventive healthcare. It is evident that further research is required in this direction.

V. Conclusions

Since the introduction of the PHS concept and vision in the 1990s, systematic support to research and development has helped overcome many technological challenges and realise the first generations of prototype PHS, e.g. in the form of wearable systems. Early evidence suggests that PHS can bring significant benefits to healthcare systems and individuals. Assistance towards the wide deployment and integration of the first PHS generations in healthcare systems will be a major stream of activity in the forthcoming future. In parallel, continued research activities will lead to new generations of PHS, increasing their spectrum of applications and, consequently, their overall benefits. The developments on both fronts during the next 5-10 years are eagerly anticipated.

Disclaimer

* The views developed in this article are those of the authors and do not reflect necessarily the official position of the European Commission.

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