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Telemedicine to Monitor Elderly Patients with Chronic Diseases, with a Special Focus on Patients with Chronic Heart Failure

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Abstract

Chronic diseases are one of the most difficult challenges to the beginning of the twentieth century. Monitoring patients with chronic diseases, especially in chronic heart failure or diabetes mellitus, using telemedicine systems is a potential means for optimizing the management of these patients, even in elderly patients. The e-care project is developing an "intelligent" communicative platform enabling the home monitoring of patients with heart failure, using non-invasive sensors, with additional contextual information and patients' profile. As a result, this platform will assist health care professionals by providing an automated processing of these sensors' transmitted data in order to detect and report signs of cardiac decompensation early or wrong adherence to therapy.

Keywords: Telemedicine; Chronic disease; Elderly patients; Heart failure; Detecting signs of cardiac decompensation

Chronic Diseases

One of the greatest challenges that will face health care professionals to the beginning of the twentieth century will be the increasing burden of chronic diseases. Greater longevity, modification of lifestyles and exposure to chronic disease risk factors (e.g. inactivity, tobacco, too rich and greasy food…), and the growing ability to intervene to keep people alive that previously would have died has combined to change the burden of diseases confronting health systems [1]. Chronic diseases can have a profound impact on the health and quality of life of elderlies, not to mention the financial burden that is often associated with long-term illness.

These chronic diseases or disorders are defined by the World Health Organization (WHO) as requiring "ongoing management over a period of years or decades" and cover a wide range of health problems [2]. In Europe, the OMS provides an "epidemic" of chronic diseases in the next 20 years. The four main expected chronic diseases are: heart failure (HF), chronic obstructive pulmonary disease (COPD), cognitive disorders (as Alzheimer's disease) and cancers. Other disorders may also be observed in the future as diabetes mellitus, obesity, hypertension, renal failure and anemia. Four chronic diseases: heart disease, cancer, stroke, and diabetes currently cause almost two-thirds of all deaths each year in the United States. About 80% of older adults have at least one chronic disease, and 68% have at least two.

Increased life expectancy generates changes in the leading causes of morbidity and mortality with more than 70% attributable to chronic diseases [3]. More than 15 million patients today contract such diseases and the expected figure amounts to 20 million by 2020.

Telemedicine

To our experience, these conditions require a complex response, taken into account several conditions in the same patients, over an extended time period that involves coordinated inputs from a wide range of health professionals and access to essential medicines and monitoring systems, all of which need to be optimally embedded within a system that promotes patient empowerment and home support.

In response to the emerging challenge posed by chronic diseases, several countries have experimented with new models of healthcare delivery that can achieve better coordination of services across the continuum of care [1,3]. Telemedicine may offer a promising system in such patients with chronic diseases, especially in frailty or too good condition patients [3]. This is particularly the case in chronic conditions in which early detection of impairment and/or complication may be detected.

A lot of the sickness, disability and even death associated with chronic disease can be avoided through preventive measures and telemedicine and telemonitoring. Moreover when an older person is diagnosed with a chronic condition, there is an immediate feeling of facing a loss of freedom and autonomy, a sense that his or her days of living independently at home are numbered. Telemedicine system offers the possibility of a high patient quality of life at home.

Nevertheless, the results of telemonitoring studies and meta-analyses have been controversial. In reviews assessing these methods, telemedicine approaches range from computer-based support systems to ones founded on structured telephone support, or even to programs led by nurses and physicians [4,5]. Thereby, it is difficult to have a definitive opinion based on what we know now on whether or not telemedicine has a significant role to play in chronic diseases.

In our knowledge, telemedicine (telemonitoring) have demonstrated their efficacy in two chronic disorders: heart failure [4] and type 1 diabetes mellitus [6]. To our opinion, telemonitoring is particularly adapted in chronic disease to avoid iterative hospitalizations.

Heart Failure

In France, nearly 1 million people are affected by heart failure (HF) and 120,000 new cases emerge each year. HF is defined by a high level of mortality (50% of deaths occur within 5 years of early symptoms), a major disability to the daily life of sufferers (shortness of breath, fatigue, etc.) and prolonged and recurring hospitalizations [7].

Chronic HF diminishes the quality of life of the patients and has a major economic impact on the health care costs coming primarily from the high cost of re-hospitalization (leading cause of hospitalization among people aged over 65) and from the recurrent episodes of cardiac decompensation [7,8].

HF main symptoms (patient's signs) consist in shortness of breath associated with strain which may remain when at rest and fatigue possibly worsening with the aggravation of the disease [7,8]. In the event of a cardiac decompensation, fluid retention signs (weight gain, edema) occur. Such signs may worsen and eventually threaten patients' life (acute pulmonary edema possibly leading to asphyxiation and cardiac arrest). In practice, the main causes of cardiac muscle deterioration are: high blood pressure; coronary artery disease; heart valve(s) dysfunction; tachycardia; anemia; pneumonia and the lack of adherence to lifestyle changes and therapy [7-9].

Current patients care aims at improving their quality of life through: alleviating symptoms (shortness of breath, fatigue, etc.); allowing for the activities of everyday life; preventing cardiac decompensation episodes and reducing hospital stays; and slowing the progression of the disease, and reducing its mortality rate [1,8].

The management of chronic HF is currently based on 2 components: 1) a non-pharmacological based treatment related to the prescription of dietary practices and regular physical activity. Such diet and hygiene education is a key element of the therapeutic patient education; and 2) a well-established and efficient pharmacological treatment (drugs) against HF [1].

In order to improve chronic HF care, the most relevant solution consists in cardiac decompensation prevention by anticipating the symptoms via a regular monitoring of vital parameters and to promote adherence to lifestyle changes and therapy [9]. This is the "philosophic" objectives of telemedicine, especially telemonitoring.

Telemedicine in Heart Failure

Meta-analyses have suggested that telemedicine, with heath care monitoring (patients himself or health care professionals), can reduce morbidity and mortality in patients with chronic HF. In the exhaustive meta-analysis from Anker et al. 11 studies were analyzed in the setting of a comparison between the effects of telemonitoring versus usual care (noninvasive telemedicine) [4]. Telemonitoring was found to reduce the following rates: all-cause mortality (10.4% *versus* 15.4%; P<0.0001); all cause hospital admission (47.2% versus 52.1%; P=0.02); hospital admission related to chronic HF (22.4% *versus* 28.5%; P=0.008).

Still, 2 prospective clinical trials have produced results that do not support these findings [4]. The Tele-HF trial randomly assigned patients hospitalized for HF to either telemonitoring (n = 826) or standard care (n=827) [10]. In this trial, no significant difference was noted between the telemonitoring and control groups in terms of rate of any re-admission or death from any cause within 180 days of inclusion (HR: 1.04; 95% CI: 0.91-1.19).

The TIM-HF trial in Germany randomly assigned stable chronic HF patients to either telemonitoring (n=354) or usual care (n=356) [11]. In this trial, the total mortality rate for the primary outcome of death for any cause was 8.4 per 100 patient-years of follow-up in the telemedical group, compared to 8.7 per 100 patient-years of follow-up in the usual-care group (HR: 0.97; 95% CI: 0.67-1.41; P=0.87).

In France, several telemedicine projects have been developed these latter years in chronic HF, such as:

- SCAD ("Suivi Cardiologique A Distance, remote cardiological monitoring");

- PIMP's ("Plateforme Interactive Médecins Patients santé", doctor-patient interactive healthcare platform);

- OSICAT ("Optimisation de la Surveillance Ambulatoire des Insuffisants CArdiaques par Télécardiologie", optimization of ambulatory heart failure monitoring with telecardiology);

- MEDICA ("Monitorage Electronique à Domicile de l'Insuffisance CArdiaque chronique", home electronic monitoring of chronic heart failure) [12-15]. At the time of writing, no published results were available from these projects.

All these projects are non-invasive and designed to enable patient management at home or in nursing homes. They are mostly based on standard tools for monitoring chronic HF, namely blood pressure monitors, weighing scales, and so on, at times integrating tools enabling the feedback and transmission of collected information (Bluetooth, 3G, 4G, etc.) as well as patient-healthcare professional interaction (call center, digital tablet, website, etc.) [5]. A few projects have also integrated motivational and educational tools. The PIMP's project also includes biological telemonitoring, with brain natriuretic peptide (BNP) telemonitoring [13]. These projects are based on prospective or cohort studies of HF patients, with widely varying sample sizes of 100-1000 patients, and different follow-up periods ranging from 3 months to 2 years, for the most part stemming from "evidence-based medicine" [5]. It is important to emphasize that the objectives or indicators of these various projects vary from modest to the more ambitious, defined as anything from improved morbidity and mortality to reduced readmissions, enhanced quality of life, and improved health economic costs.

An Automatized Intelligent Non-Intrusive Project of Telemedicine in Chronic Heart Failure: The E-care PROJECT

In chronic HF, the E-care platform designed in the framework of the «Investissements d'Avenir » program (national program from the French Government to promote translational research, 2010) and implemented at the University Hospital Strasbourg (in Strasbourg, France) since October 2013 will be used to monitor patients at home:

to detect cardiac decompensation; to promote adherence to treatment; and to facilitate interaction between healthcare professionals [16].

E-care is an interconnecting, intelligent, and non-intrusive platform, using non-invasive Bluetooth measuring devices (BP, heart rate, oxygen saturation, and weight). The E-care platform provides assistance to the health care professionals by automating the processing of data sent from the sensors, automatically generating alerts in order to detect and report risk situations of HF early (Figure 1) [16].

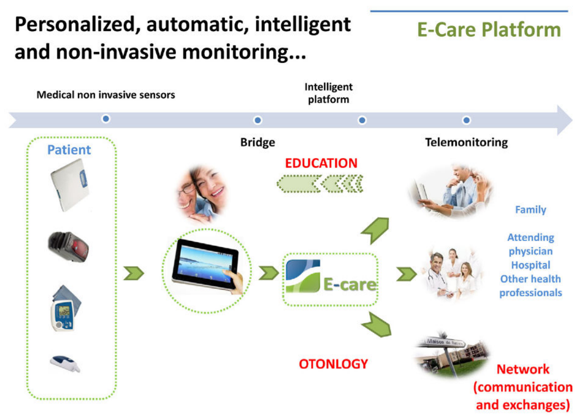

Figure 1: The E-care platform.

For each patient, E-care processes in real-time the personal data collected by the sensors, then analyzing it in conjunction with the domain ontologies describing their pathologies, medications, and symptoms [5]. This first inference constitutes its first learning process by adding new information to the patient ontology. In the second stage, E-care consolidates all the information relative to all patients in order to enhance the system. New rules are then added by searching for similar patterns describing critical events. This second step is effective as soon as there is a lot of data to process.

This platform also enables the sharing and management of heterogeneous data so as to integrate the necessary information required for monitoring any underlying pathology, such as HF, diabetes mellitus, renal failure, respiratory insufficiency, and so on [16].

The system has been deployed since October 2013 in a 20-bed unit of the Department of Internal Medicine, Diabetes and Metabolic Diseases of the Medical Clinic B of the Strasbourg University Hospital (in Strasbourg, France) [17]. This unit is "open" to the emergency wards. Around 800 patients are hospitalized in this unit per year. To date, more than 180 patients have been included in the different phases of the study. The patient profile included in this experiment was: elderly patient, with several chronic diseases as: chronic HF>60%; anemia>40%; arrhythmia due to atrial fibrillation (AAF) >30%; type 2 diabetes >30%; COPD >30%; cancer 20%; chronic renal failure >15%; and dementia >15% [17]. In 25% of cases, patients present a total loss of autonomy.

In the first experimental phase, we validated the selected sensors deployed as part of the E-care platform using a protocol of comparative measurements from conventional hospital measuring devices (BP, heart rate, oxygen saturation, and weight) and those of the E-care system [5].

In the second phase of the experimentation, over 150 patients have been enrolled and over 1,500 measurements performed [17]. Nurses use the E-care measurement devices on a daily basis when carrying out their patient rounds. This phase relies notably on the establishment of a new human-machine interface and new inference engine. This phase includes a satisfaction and practical use survey of the system's ergonomics, filled out by caregivers and patients. A preliminary analysis of the relevance of alerts shows the relevance of these alerts, admittedly on a limited number of patients with acute heart failure during hospitalization (12 patients). The continuous gathering of data during this second phase enables us to obtain the critical mass of patients needed to conduct a more detailed analysis of the relevance of the alerts.

Future Developments and Innovations for the E-Care Platform

Our future projects of telemonitoring in chronic diseases aims at exploiting the generic E-care medical platform in order to monitor patients, especially elderly patients with several comorbidities, based at home [16,17]. It will enable us to establish a generic detection process, at the earliest possible stage, for any abnormal evolution and consequently improve the medical diagnosis for patients with one or several chronic diseases such as: firstly, chronic HF and diabetes mellitus; than COPD and renal failure [18].

Our objectives are to successively develop the E-care generic platform through:

- Implementation of several non-intrusive sensors, such as: glucometers, thermometers… scales, and electrocardiography to monitor vital signs [19];

- Implementation of an electronic pillbox to promote therapy adherence;

- Insertion of a questionnaire to monitor patients' hygiene and diet;

- Development of a questionnaire to monitor patients' therapy adherence together with additional contextual information and patients' profile (e.g. patient's age and medical history, etc.).

Moreover, the patients will fully benefit from therapeutic education through a development of a comprehensive and complete Man-Computer interface.

Information monitoring and data collection will then be utilized to examine the combined evolution of all patients' vital signs, behavior and personal health practices [16]. This will aim at detecting the most relevant repetitive sequences (markers) allowing for the earliest and best suited medical support for a given patient, for all his chronic diseases, in a perspective of a "transversal view", with several comorbidities, not only a "longitudinal view" with one disease) [18].

Semantic Web technologies, used by E-care, provide us with a solid approach to the management of the associated information and processes management. They are being used increasingly for a broad spectrum of applications within which the domain expertise is modeled and formalized (ontology) in order to support widely diversified computer processing (thinking) [20]. Using effectively ontologies for reasoning purposes entails that an operational semantic be added, identifying how the modeled expertise of the ontology will be used for reasoning purposes and for the automated generation of new expertise and knowledge.

The number of daily data collected among a wide cohort of patients, together with their specifications and the information relating to their health practices is considerable. Statistical and data mining methodologies consequently play a key role in the acquisition of new knowledge. Data mining and ontological meta-data are powerfully correlated. Data mining technologies help build the Semantic Web and the latter helps retrieve and acquire new knowledge [20].

Our work will focus on the utilization of data mining technologies in order to enrich the ontology and to generate new knowledge. Such enrichment is defined as « adapting ontology to the need for change and the dissemination of these changes to the depending artifacts while preserving consistency ». This enrichment will generate an assessment which will take into account several quality aspects such as structure and utilization. In the defined field, we will focus on the validation of consistency and the assessment of quality. Consistency validation consists in verifying that all medical rules remain true once changes have been applied. Quality assessment allows for the changes final acceptance decision.

The first project, named INCADO ("INsuffisance CArdiaque à Domicile", funded by the Agence Régionale de Santé d'Alsace) will be focusing on chronic HF, taken as a testing disease [21]. The adapted E-care platform will monitor 100 consecutive patients with HF, at home on a daily, during at least 1 year. The patients were be recruited and followed by the University Hospital of Strasbourg (Strasbourg, France), one of the major medical care and research centers in France. It hosts more than 2000 beds and employs more than 10,000 people. It is an important reference for European City University hospitals. This study will compare the group with monitoring through the adapted E-care platform to the group without monitoring (not randomized design of the study).

In a second project, Kohonen self-organizing maps (Self-Organizing Kohonen Maps: SOM) and non-supervised learning neural networks will be utilized in order to obtain a data interpretation process showing the evolution of the vital signs [22]. Such process must be a stand-alone process, automatically self-configurable, adjustable to any change or evolution of the context and capable of building up knowledge of its own operation so as to improve during such operation. Symptoms specification taking into account the evolution of each vital sign associated with hygiene and healthy lifestyle will enable us to formalize detection at the earliest possible stage thus ensuring efficient treatments. One of the main objectives will be the consolidation of all collected data in order to enrich the ontologies to which the thinking will be applied.

Conclusions

Monitoring patients, especially elderly patients with several chronic diseases by using telemedicine systems is a potential means for optimizing the management of these patients. As recently published, elderly patients are "fond" of new technologies (even if there are not geek!) and in the majority of cases have no problem with the appropriation of these technologies (mean age of the studied patients: 80 years) [23].

The E-care project is developing an "intelligent" communicative and non-intrusive platform enabling the home monitoring of patients with such disorders (currently chronic HF). This platform will assist health care professionals by providing an automated processing of several sensors' transmitted data in order to detect and report signs of chronic disease decompensation.

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