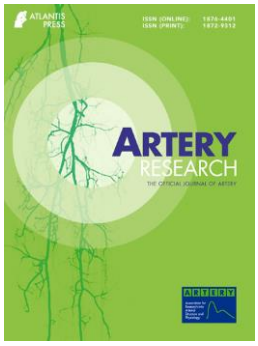

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Review

Remote telemonitoring of cardiovascular patients: Benefits, barriers, new suggestions

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Abstract Remote telemonitoring systems have been designed as a response to the new needs of home care for patients with chronic diseases. It also has the potential to ensure appropriate monitoring and treatment of patients as well as reducing the healthcare costs. Telemonitoring has been shown to be able to significantly improve the treatment outcomes of many chronic diseases, including pulmonary disorders, diabetes, hypertension, and cardiovascular diseases (CVD). Despite the promising results of telemonitoring systems regarding patient management and healthcare costs reduction, usage of this innovative technology is not as widespread as we would expect. The major barriers responsible for this are: unawareness and non-compliance of health care providers and patients, insufficient reimbursement of telemonitoring system expenses by National Health Service (NHS) and health insurance companies, unclear business models and also high costs of making necessary adjustments to change from more conventional systems to the new ones for the healthcare providers. These concerns should be addressed when designing and producing new telemonitoring systems. The focus has to be on making systems that are more user friendly, cost effective, durable with better safety standards. There should be a lot of effort to gain the support of the NHS and health insurance companies as well as to train and educate patients and health care providers in order to make them more compliant. Moreover, specific considerations must be made for special needs groups such as the elderly, those with impaired mental health or the ones that do not have access to computers easily.

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Contents

Introduction

In recent decades the average human life expectancy has grown around the world, mainly due to the improvements in social and environmental conditions as well as the scientific and technological advancements which has helped the healthcare providers to provide better clinical and para clinical services. As a result, the world population is aging in an unprecedented, pervasive and enduring way. The aging has been extraordinary and unparalleled through human history and it is going to be even more rapid in the 21th century. The aging process which is a universal phenomenon affecting almost all the countries around the world. It is also enduring meaning that the world population never returns to its younger state again.[1] The aging phenomena is going to have profound effects on many aspects of human life including health related issues.

The major health related consequence is the fact that the incidence and prevalence of chronic diseases, also known as non-communicable diseases (NCDs), is on the rise. According to the CDC reports (Center for Disease Control), as of 2017, almost 50% of adult Americans were dealing with one or more chronic conditions and 25 percent had two or more chronic health conditions at the same time.[2] The number of deaths due to the chronic diseases is also growing in most countries, despite the progress in reducing age-standardized death rates.[3] In fact, about 40 million people die due to the chronic diseases on a yearly basis which equals to 70% of annual death rate. The four major NCDs are cardiovascular diseases (CVD), cancers, chronic pulmonary disorders and diabetes. For instance heart diseases and cancer together accounted for nearly 46 percent of all deaths,[2] they are followed by respiratory diseases and diabetes which cost around 3.9 and 1.6 million yearly death, respectively.[4]

In addition to the growing prevalence and the high rate of mortality and morbidity, NCDs are costly as well. Dealing with different aspects of chronic diseases management consumes the largest portion of a nation's health budget[2] and poses a significant and long standing challenge for virtually all healthcare systems.[5] In United States total costs of diagnosed diabetes and CVDs together, were more than 550 billion of dollars, in 2012.[2] Among the prevalent NCDs, the growing burden of CVDs on national healthcare systems is well recognized amongst healthcare professionals internationally.[6] In fact, CVDs alone are not only capable of placing a burden on almost any healthcare budget, but also on the entire economy of a country. This is even more concerning when considering the middle or low income countries in which the high Costs of CVDs, can be responsible for macroeconomic losses equivalent to, up to 6.77% of their GDP.[7] In view of the fact that the chronic diseases affect people in low and middle income countries disproportionately, the growing economic burden of such diseases is able to push those countries through poverty and drain their household resources.[4]

What adds to the challenges above is the fact that the number of healthcare service providers is declining in the face of the increasing demand. According to WHO the world is going to face a 12.9 million healthcare provider shortage by 2035, as the current rate of training new health professionals do not meet the present and upcoming needs. Internal or international migration of providers has also exacerbated the problem by shaping an unfair distribution of providers between different areas. The report showed that 83 countries have failed to reach the basic expected threshold of healthcare professionals to the population ratio.[8] The most recent report of annual physician workforce projections predicted that by 2030, demand for physicians will exceed supply by a range of 40.800 to 104.900.[9] The imbalance between demand and supply for nursing professionals is also well recognized according to many global and national reports.[10] Furthermore, physicians and nurses are aging as the general population. In 10 years more than one third of current physicians will be older than 65, meaning that many of them will not be among the active health providers in near future.[11] Focusing on the trends of nurse shortage and the increasing average age of nurses, also indicates that the nurse workforce will decline below projected requirements in coming years.[12]

The enormous economic burden of chronic diseases along with the growing imbalance between the number of patients and number of healthcare providers is challenging our health care systems. In order to address this challenge, we have to seek for new solutions which would enable us to utilize our limited resources more efficiently. Our

healthcare systems should be modified in a way that reduces costs while delivering the right service to the right person at the right time. We need to identify new methods to overcome the unfair distribution of our healthcare resources and find ways to provide appropriate monitoring and treatment to the ones that do not have a good access to health services or those elderly and frail who are housebound. For instance, bringing the care directly to the patients' home can be considered an appropriate approach. In this regard, employing technologies that enables us to remotely collect clinical data from patient's home (telemonitoring) and then providing relevant clinical care to them by means of telecommunication and information technology (telemedicine) is of great value.

Telemonitoring is now defined as the remote monitoring of patients, including the use of audio, video, and other telecommunications and electronic information processing technologies to monitor patient status at a distance.[13] More precisely HT (home telemonitoring) is a particular form of telehealth that encompasses the use of remote access information and communication technologies (like telemetry devices, intelligent sensors, hand-held or wearable technologies) for the timely transmission of symptoms, physiological, and disease-related data from the patients' home to a telemonitoring center supporting clinical decisions. This would facilitate more frequent follow ups by physicians, over longer periods of time, away from hospital settings.[5] When vital signs and health status are measured daily with home telemonitoring program, irregularities can be identified early before the patient becomes critical which would prevent expensive emergency room visits and reduce preventable hospitalizations. The daily monitoring and communication between the provider and the patient allows for reinforcement of symptom management, proper use of medication and self-monitoring. This would assist the patient to be more involved in their own care, adds to their quality of life and bring us closer to the ideal of a more patient-center medicine.[14]

This paper aims to take a closer look at history, benefits and barriers of telemonitoring. We review the literature for the most recent recommendations for designing new telemonitoring devices and software and the novel solutions to overcome the current barriers of the present systems.

History of telemonitoring

The concept of using some type of communication for medical purposes roots in human history. From the aboriginal peoples of Australia who were using "message sticks" as a tool for delivering information pertaining to tribal gatherings, diseases and deaths[15] to the use of smoke signals in African tribes to send alarming sign for a disease outbreak[16] or using heliograph or bonfires by Europeans for transmitting information about bubonic plague[17] all were applying some methods of long distance communication for a health related purpose. The invention of telephone by Alexander Graham Bell in 1876 was a breakthrough. The lancet reported its first application for medical purposes[16] and the technology later used in the American Civil War to transmit casualty list and order medical supplies.[17] The telephone is still widely used in many clinical and para clinical settings.

Many would agree that the first steps toward the modern telemonitoring were made by Dutch physiologist Einthoven in 1905 when he made the ECG a practical reality by combining several different innovations. A few years later he succeeded to transmit electrocardiograms from a hospital to his lab by combining his improved galvanometer with the emerging telephone technology.[15] Next revolutionary innovation was Radio which soon became widely accepted and played a major role during world war one.[18] Later in 1950s transmitting X-ray and electrocardiograms between distant areas was routinely done owing to the innovations founded by Cooley et al.[15]

The ambitious man spaced flight programs conducted by NASA further pushed for the new practical innovations for telemonitoring and the facilities for providing necessary healthcare for the astronauts in 1969s. The NASA scientist's endeavors for developing unprecedented telemonitoring and telecommunication systems later became the basis for modern telehealth technologies.[19] With the growing enthusiast and need for such systems the first operational telecommunicating system was launched in Boston in 1968, linking a medical station at airport to a general hospital. Ever since the telemedicine and telemonitoring have been emerging concepts and widely used around the world.

Today the emerging advances of information technology, the advent of internet and the growing trend of people's access to it, and the challenges facing the healthcare systems are all contributing to the growth of this field of science and engineering.

Review of literature

Review the literature shows that many clinical conditions have been considered as the main targets for employing telemonitoring, that among them, monitoring of pulmonary disorders, diabetes, hypertension, and heart failure are the tops of the table.

Utility of telemedicine has been studied on chronic pulmonary conditions such as pulmonary transplant, asthma and COPD. These trials have demonstrated ability of telemonitoring to identify early changes in patients conditions, thus supporting immediate intervention and avoiding exacerbation.[20]

Latest reviews on usage of telemonitoring for management of diabetes have revealed positive improvement in HbA1c level in type 1 and type 2 diabetic patients, improved glycemic control in gestational diabetes and effective screening and monitoring of diabetic retinopathy and also high acceptance among participants.[21–23] Although heterogeneity in the results shows need for further trials to support the role of telemonitoring in diabetes management.[24]

Similarly, projects involving patients with hypertension have also demonstrated the ability of telemonitoring to control systolic and diastolic blood pressure and prevent its cardiovascular consequences.[25–28] Blood pressure telemonitoring (BPT), allows remote data transmission of BP and additional information on patients' health status from their living site or from a community setting to the doctor's office or the hospital. Several randomized studies have documented a significant BP reduction with regular BPT compared to usual care.[29] A study conducted

on 450 adults with uncontrolled blood pressure aimed to discuss effect of home blood pressure telemonitoring with pharmacist case management and compare it with usual care. Results showed that, compared to usual primary care, home telemonitoring resulted in large improvements in BP control and substantial decreases in BP over 12 months. Compared to Usual Care patients, Telemonitoring Intervention patients had greater self-reported adherence to their antihypertensive medication and sodium restriction. The intervention also improved some aspects of patient satisfaction and appeared to have acceptable safety.[30]

Early diagnostic procedures and worldwide demographic aging have resulted in increasing number of patients with chronic cardiovascular diseases (CVD). The increasing burden of CVD necessitates the investigation of effectiveness of telemonitoring in CVD. Telecardiology applications can be useful in primary and secondary prevention of cardiovascular diseases, diagnosis of acute myocardial infarction, rehabilitation after cardiac events, management of chronic heart failure, arrhythmias and management of cardiac implantable electronic devices. Recently multiple systematic reviews have investigated the effectiveness of telemonitoring in CVD. According to literature pre-hospital electrocardiogram for the diagnosis of ST-elevation myocardial infarction can shorten the delay to reperfusion and lower mortality. Reviews that have studied effectiveness of telemonitoring for HF demonstrated a reduced risk of mortality, fewer hospitalizations, reduced health care costs and improved quality of life compared to usual care. It has been reported in two syntheses of the effectiveness of telemonitoring across disease groups that the evidence supporting the efficacy of telemonitoring is most favorable for HF and hypertension compared to other forms of chronic disease.[6,31] Although a multicentric controlled trial conducted on 1653 patients recently hospitalized with heart failure, compare telemonitoring with usual care. There were no significant differences between the two groups with respect to the secondary end points or the time to the primary end point or its components.[32] In the other hand at the same year a Cochrane review concluded that telemonitoring of patients with heart failure reduced the rate of death from any cause by 44% and the rate of heart failure related hospitalization by 21%, however many of them were small studies and quality of methods used in different studies was variable.[33]

Telecardiology can also help in first detection of new atrial fibrillation (A.F), home management of chronic A.F and home monitoring of cardiac implantable devices is feasible and associated with an early detection of medical and technical events.[31,34]

As telemedicine can help in early detection and shorten the delay to treatment it can also be used for early diagnosis of ischemic stroke. High stroke score are related to delayed door-to-needle time (DTN)[35] thus trials have done to study effectiveness of telemonitoring to reduce DTN. telestroke uses video conference (VC) technology to allow off-site experts to provide stroke thrombolysis decision support to less experienced front line clinicians. Telestroke was associated with a significant increase in thrombolysis rate and reduction in door-to-needle time in provincial hospitals indicating improved patient care.[36]

Benefits of telemonitoring

Growing burden of chronic diseases on National Healthcare System (NHS) necessitates the investigation on innovative models to provide evidence-based care to promote early identification of exacerbations and early intervention to minimize their severity. Increasing number of patients with cardiovascular disease and as a result, chronic heart failure (CHF), is becoming a health issue. Almost half of the patients admitted to hospital for HF are readmitted within 6 months. These frequent hospital admissions contribute to the high cost of HF management. Up to 70% of HF cases are proceeded by hypertension and this shows the need for proper management of HTN and other cardiovascular diseases.[6] Therefore, this innovative healthcare management solution can lead to major improvements in disease treatment. Review of literature showed that those patients with chronic conditions in the telemonitoring group were significantly less likely to visit the emergency room, less likely to require an emergency hospitalization, less likely to have an elective hospitalization and spent fewer days in bed, compared to those in the standard treatment group.[37] Additionally, those in the telemonitoring group have lower mortality rates than those who are not tracked remotely and also it can reduce morbidity in conditions like stroke by decreasing door-to-needle time.[36]

Suitable candidates for telemonitoring are: 1) High acuity patients, i.e., heart failure, chronic pulmonary/lung conditions, arrhythmia, patients with pacemaker, ICD, CRT-D, loop recorders and other concerns for close monitoring; 2) Individuals who are susceptible to frequent hospital and/or emergency room visits; 3) Non-compliant patients who can benefit from the system reminders and ease of use; 4) patients who live in rural areas or have difficulty accessing health care. In—home telemonitoring offers many benefits for providers and their patients, this system can provide patients with a new sense of security knowing the clinicians are monitoring their health status daily, telemonitoring can effectively reduce preventable visits and hospitalizations that this is potentially cost-effective, it can encourages self-management, adherence to care plan and medication compliance, it can provide objective data and trending for physician review, it enhances the health care delivery in rural areas by facilitating access to diagnostic tests as well as increasing communication between primary health care providers and specialists, Clinically, telemonitoring significantly improve treatment outcomes for patients with chronic diseases.[6,20,21,31,38]

Barriers of telemonitoring

Due to barriers on patient and organizational levels, a widespread diffusion of telemonitoring has not been reached. As results, the major identified barriers include missing reimbursement of telemonitoring systems by national health services and health insurances, unclear business models and high costs of change for the health care providers for making adjustments. Health insurances declared that the studies showing cost reductions do not convince them due to a lack of consistent methodology and a different cost bases in studies when compared to their own

cost base for a particular case of illness.[39] As majority of total and social care budget is spent on treatment and care of patients with long-term-conditions (LTC), several trials have been done from National Health Service (NHS) prospective to study cost-effectiveness of using telemedicine services for follow up of chronic diseases and there is a wide discrepancy in the results of different trials.[40,41] On the other hand, monitoring patient safety, patient's privacy, professional reliability are other barriers to its widespread use. Mobile health and telemedicine are two most popular and widely distributed to communicate doctors and patients, the specific term is mobile health or m-Health.[29] However, it is a challenge for food and drug administration (FDA) to ensure its safety. FDA has authority over "mobile medical applications" but m-Health product that incorporate clinical decision support are not regulated by FDA. The true challenge is protect market from unsafe and ineffective products while also not to prevent industry's long term potentials.[42] The cardiovascular diseases among the newborn infants are also needed to be investigated to diminish the following complications during their life.[43—46]

Also, poor device usability, insufficient training to use technology, lack of computer skills and low self-efficacy generally has been reported among patients using telemonitoring.[47,48] That might be the reason that care providers may have the idea that the care for elderly patients with telemonitoring will be more laborious.[49] But according to studies the most common factor influencing the success of telemonitoring was the patient's percipience of beneficial effects of this system.[50] In addition, another common technological problem when using telemonitoring is the lack of reliability of the patients' Internet connection. The living environment of patients may play a role in the uptake of telemonitoring.[51] Furthermore, medical personnel might refuse to use telemonitoring systems due to fear of loss of power, or lack of knowledge how to operate the system, and some nurses' fear to become redundant.[52]

New suggestions and recommendations

To design and implement an appropriate remote telemonitoring system, all pointed barriers should be considered. Perceptions on effectiveness of tele-homecare programs for achieving intended outcomes; tailoring of tele-homecare programs to patient characteristics and needs; relationship and communication between patient, nurse, and other health care professional users of tele-homecare; home health organizational process and culture; and technology quality, capability, and usability impacted the sustainability of tele-homecare programs.

Many trials have reported no significant difference or small improvement in condition of patients undergoing telemonitoring but most of them had a short term follow up period and it seems unlikely that in a chronic disease any intervention can have much effect unless applied for a long period. Also there might be bias on reporting the results as studies are not blinded. So it is suggested to conduct blinded studies with longer duration of follow up. Also due to some heterogeneity in the results of studies, further trials to identify subgroups of patients who are more likely to attain benefits of telemonitoring system is necessary. With regard to the future prospects of telemonitoring, there is still a need for further high quality studies particularly on the national level concerning the clinical, economic and other outcomes of telemonitoring compared to the standard therapy.

On the other hand, the final goal of software designers for designing new telemonitoring system should be focused on some main points including cost, easiness and usability of using device, possibility of long-term use, possibility of support by insurance, possibility to train of staff and patient, suitability for elderly patients or those with impaired concentration, easily access to computer, and assuring both patients and monitoring nurse for safety and effectiveness of new device. In this context, to design an acceptable remote telemonitoring system, the following characteristics in patients with cardiovascular disorders can be suggested: 1) it should be possible to long-term recording data; 2) fitting the volume of transmitted data and characteristics of the designed system; 3) the possibility of processing data as the real time; 4) processing data of several patients simultaneously; 5) correct diagnosis of cardiac acute events especially arrhythmias; 6) possible implementation in the country; 7) maintaining security and privacy; and acceptable technical costs (high cost-effectiveness).

Compliance with ethical standards

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Conflict of interest

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Ethical approval

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