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# m-Health: A Framework for a Wireless Solution in the Self-Management of Diabetics

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## Biographical Notes

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# m-Health: A Framework for a Wireless Solution in the Self-Management of Diabetics


## Abstract

*The concept of disease management facilitated through wireless technology could mean a step forward towards a more effective and efficient care of diabetics out of hospitals. In this paper we begin with an overview of diabetes and diabetics' needs. The concept of disease management is described next along with the evidence that such programs improve diabetics' condition. The challenges and benefits of adopting a wireless solution to facilitate the disease management of diabetics are discussed next. A model is then proposed for a typical wireless implementation that outlines the flow of information and communication among the key participants within the diabetes environment. The business case for diabetes management is given next from the perspective of both the patient and the healthcare system. Finally, implications for both healthcare and patients as well as possible directions for future development are also discussed.*


**Keywords:** *mobile, wireless, healthcare application, diabetes, disease management*

## 1. Introduction

Diabetes is costing Canada and the U.S. approximately $9 and $98 billion per year respectively [17, 21]. This chronic disease requires almost hour-to-hour management for items such as dietary intake, calorie counting and/or vital sign monitoring. Due to known and unknown factors associated with aging population and modern life style changes, the incidence of diabetes has been increasing rapidly [34]. The growth, combined with augmented challenges in the availability of funding and personnel in the healthcare sector, led to the idea of a new approach in dealing with diabetes: disease management through mobile health.

This paper discusses the value proposition of wireless technology to day-to-day diabetes management for patients cared outside a clinical environment, with the patients' active involvement.

The paper begins with an overview of diabetes and diabetics' needs. The concept of disease management is described next along with evidence that such programs improve patients' condition and life quality.

Since self-management offers "the distinct possibility of predicting and thus avoiding serious complications" [32], we next investigate what exact needs a self-management program tailored to diabetics should address.

The third section discusses the possibility of offering wireless solutions to diabetics. Wireless technology is becoming increasingly popular in North America and one of the main drivers for its use in healthcare appears to be the needs of patients cared outside a clinical environment. Therefore, we address the challenges of implementing wireless monitoring from two perspectives, people and technology, and cite relevant examples of wireless solutions currently in use or in development.

The fourth section attempts to answer the question "Could wireless technology bring real benefits to the condition of diabetes patients cared away from a clinical environment without significant costs from the healthcare system?". In doing so, the paper presents a wireless solution for diabetes management that includes the remote monitoring of patients' condition. Such a simple system should be able to "realize data-capture in remote areas or by the patient himself" [4] and to expedite the data flow in the monitoring process.

The business case for diabetes management is given next from the perspective of both the patient and the healthcare system. The business case incorporates the benefits associated with treating diabetes away from a clinical environment.

Finally, some conclusions are presented along with a discussion regarding potential directions of evolution taking into account the expected development of technology as well as of the healthcare sector in Canada.

## 2. Overview of Diabetes

Diabetes is a chronic disease affecting hundreds of millions of people around the world regardless of age, gender, socio-economic, cultural, and educational background [9]. Estimates of diabetics in the U.S. {over 18 million [1]}, Canada {more than 2 million [7]}, Europe {over 30 million [41]}, and the Western Pacific {30 million [56]} show that approximately one in ten people is diagnosed with diabetes, while another two out of ten are at risk and classified as "pre-diabetes" [1, 56]. As an important cause of death, diabetes refers to the body's inability to produce any or enough insulin. Insulin is used to convert the sugar (found in carbohydrates consumed by the individual) into energy needed to fuel the body. In the absence of insulin, unconverted sugar can result in complications such as the damage and even failure of organs, including eyes, kidneys, and heart. With proper management and care these complications can be prevented and the patient can live a long and normal life. Sadly, the majority of complications is consequent of the patient's incompliance with the prescribed instructions of the physician and other experts (e.g. dietician). This is an area of growing concern for the healthcare industry and Section 2 reviews the most recent approaches addressing the incompliance.

### 2.1 Patients' Needs

It is important to understand the patient's needs and the elements of patient's life that are of high interest after the initial diagnoses of diabetes (information in this section is based on [1]). Diabetics are classified in four categories, Type 1 (characterized by the dependence of insulin administration), Type 2 (varying levels of insulin-related issues resulting in a variety of potential treatment plans), Gestational (a special case of diabetes arising during pregnancy), and Other (disease is attributed to any one of several factors, such as drug-related complications). From the four categories, Type 2 patients represent the vast majority of diabetics (90-95%) and their needs are the most varied. By examining a typical Type 2 patient's needs, an understanding of the requirements for the other diabetics will also be facilitated.

First and foremost, it is important to identify that the primary goal of all diabetic treatment is the stabilization of blood sugar level that may vary as a result of many potential factors, such as stress and diet.

The second item of interest is the symptoms exhibited by the diabetic. Unlike Type 1, Type 2 diabetics may not show any symptoms even though they can be undiagnosed cases of diabetes.

Another issue with Type 2 diabetics is that the disease may be controlled by a change in life style (such as physical exercise) and/or in diet. While this is an area where the patient is in complete control, compliance with suggested life changes is the most prominent problem among diabetics.

In the event that exercise and diet do not restore blood sugar levels to normal, oral agents (specific drugs) can aid. There are several categories of drugs available and they all share the goal of lowering and controlling blood sugar. Proper and continuous administration is vital, and, again, compliance with the drug prescription instructions is problematic. For more severe cases, insulin injections may be required between once and several times per day.

Finally, a critical component in the proper management of diabetes is self-testing or monitoring of blood sugar levels. There are several approaches for this task, but again patients are not always responsible in monitoring their indicators regularly, many people simply ignoring the data or blaming it to external conditions such as a faulty reading.

In summary, diabetics need to stabilize their blood glucose levels and in doing so they invoke one or a combination of the following: exercise, diet, oral agents (prescription drugs), insulin, and self-monitoring of blood sugar levels. The main issue with all of the above requirements is compliance. Incompliance may occur due to resistance to change or simply lack of education. Behavior modification is critical among diabetics, and the next section discusses one approach facilitating this adaptation found in disease management programs.

## 2.2 Disease Management

Remote care of diabetics who are not experiencing a serious condition tends to be the preferred option for both the healthcare system and the patients today. The global population aged over 65 is expected to increase by 88% in the next 25 years. This demographic change combined with the expanding incidence of Type 2 diabetes, especially in the Western Hemisphere, will yield the existing health resources and methods insufficient [34]. Consequently, the healthcare system is under great pressure to translate the care of diabetics to a non-clinical environment for those patients who are not experiencing severe conditions.

Sending patients home would not mean neglecting them. On the contrary, applying the concept of ***disease management*** should mean an even better treatment. The *Disease Management Association of America* defines disease management as "a system of coordinated healthcare interventions and communications, for populations with conditions in which patient self-care efforts are significant" [27]. Important components of the disease management paradigm include collaboration between physicians and support-service providers, patient self-management education (primary prevention, behavior modification programs, compliance, and monitoring), outcomes measurement, evaluation, management and communication between patient, physician, health plan and ancillary for reporting and feedback.

Behavior modification, compliance, and monitoring are areas that can be enhanced through a combination of education and intervention. Education can be *passive* through information sessions organized by diabetes educators, as well as *active* by the patient retrieving and reviewing relevant literature. Both of these aspects can be facilitated by technology as outlined in Table 1.

A key issue with diabetes management is that the required treatment plan varies among patients depending on their characteristics [36]. Therefore, in developing a system that utilizes wireless technology, ***mass personalization*** (not in its typical marketing context) where different services are tailored to and used differently by each patient is a key success factor.

## 2.3 Disease Management of Diabetes & Technology

The discussion to this point has included the identification of the diabetics' needs and the concept of disease management. This section explores the justification of using technology in facilitating diabetes management. In doing so, a literature review of published studies is provided. In addition, Table 1 outlines the key components of diabetes management with their various activities and the value that mobility and wireless technology brings to a potential solution addressing the needed activities.

Several studies have identified the issue of incompliance with a diabetic's prescribed plan-of-care and some of them examine different means of improving compliance [5, 15, 23, 26, 31, 42, 48, 49, 50, 53, 57]. Furthermore, researchers explored the area of disease and self-management, with some studying the effects of these programs on diabetes [10, 18, 19, 25, 28, 35, 37, 39, 40, 43, 47, 52, 60]. From all of the above studies those of particular interest are summarized next.

Research studies supporting the effectiveness of diabetes management programs are described first. Norris et al. [39] proved that self-management training in Type 2 diabetes is effective, particularly in the short term, in improving the frequency and accuracy of self-monitoring of blood glucose, self-reported dietary habits, glycemic control, and knowledge. Glasgow et al. [19] concluded that quality of care provided to the vast majority of diabetics is problematic due to the current prevalence of the acute model of care. They go on to propose seven key characteristics of effective diabetes management programs, three of which focus on the patient; these are:

- involving proactive contacts, monitoring, and reminders,
- incorporating the patient as an active participant and use patient-centered collaborative goal setting, and finally
- using clinical information systems, such as diabetes registries and electronic medical records, to improve the quality of care.

Pastors et al. [43] complement the above studies by proving the clinical effectiveness of *Medical Nutrition Therapy* in diabetes management. This is the use of specific nutrition services to treat an illness such as diabetes and involves the assessment of the patient and the treatment, counseling, and the use of nutrition supplements.

Burge [5] focuses on another component of disease management, *Self-Monitoring of Blood Glucose (SMBG)*. Burge reports on the positive relationship between rigorous blood glucose monitoring at home and improved glycemic control. Karter et al. [25] as well as Franciosi et al. [18] proved that SMBG is important in improving metabolic control if made part of patient's self-management.

The above studies proved that self-management is an effective approach in stabilizing patient's blood glucose levels, which subsequently reduces the incidence of further complications, and improves the patient's quality of life. Health care providers stress it is important to consider the patient's beliefs about the disease and the treatment and work together with the patient in developing a realistic plan that if followed will have the desired effects. Renders [47] showed intervention to be effective in diabetes management but it needs to be patient-centric.

Having demonstrated that diabetes management programs are effective, the next question becomes whether technology has a place in this environment. First, Chase et al. [10] proved that the electronic transmission of blood glucose levels at regular intervals, replacing the need for a clinic visit, yields similar levels of glucose control and subsequent incidence of complications to those of patients receiving regular standard care. Therefore, the patient benefits by not having to make visits as frequently and the health care provider has more time to allocate to patients, while reducing costs for

both. Furthermore, personalized computer-generated reports have been demonstrated to lower patients' blood glucose level. Therefore, technology has been shown to be an effective approach in enhancing patients' condition.

Finally, the discussion in this section shows that the combination of disease management programs, self-management training, education, and the use of technology can improve patients' health and quality of life (by fostering self-efficacy and reducing the incidence of health-related complications), while at the same time benefiting the health care system. Based on the information found in these studies, Table 1 presents the value of wireless technology in addressing patients' needs. Drivers for using wireless technology include:

- enhanced mobility of patients;
- constant reachability;
- continuous monitoring of a patient's health (through specific indicators, e.g. blood glucose); and,
- immediate access to critical services.

A detailed description of the proposed wireless solution for the self-management of diabetics, along with its benefits and challenges is presented in the remaining portion of this paper.

## 3. Addressing Diabetics' Needs through Wireless Solutions

This section explores the challenges as well as the benefits of utilizing wireless technology in addressing the information and communication needs of diabetics. Furthermore, the types of mobile information and/or communication that a typical diabetic may require are identified.

### 3.1 Do Diabetics Cared of Outside Hospitals Need Mobile Answers to Their Needs?

The question is substantiated by the fact that mobility in the context of communication and information "should not be understood simply as a new distribution channel, a mobile Internet, or a substitute for PCs" [62]. A mobile application is justified by the relative location of the user when a certain service is needed, by the urgency, or by the relative importance of the service required [33]. All three factors are present in the framework discussed in this paper:

- ***Location.*** Diabetics have inherent mobility when changing space position for going to work, school, shopping, walking, or various other places. It is important for them to have self-confidence and feel as being in permanent contact with nurses or doctors.
- ***Utility.*** For the success of diabetes management it is essential for patients to be monitored continuously at least in terms of blood glucose level so as their medical condition remain within tolerable limits. Also the patients must be constantly reminded to comply with the treatment pattern: take pills, start or stop a medication or a diet, visit a doctor for periodical consults, etc.
- ***Urgency.*** In general, time is not a critical factor for diabetics. However in extreme cases, when the health equilibrium is broken, some patients may need a fast intervention. This feature would make patients feel safe as being constantly cared of.

Additional reasons for mobile solutions for diabetics' cared out away of hospitals, refer to patient data collecting and analyzing. By utilizing electronic devices on this purpose, there is a major potential to improve the quality of care for these patients including by quick interventions, when necessary. In the same time, this approach also significantly reduces nurses and doctors' workload generated by taking care of remote diabetes patients.

After seeing that the above-mentioned patients would need mobile solutions for several reasons among which the most important are constant monitoring, self-confidence, reinforcing of safety feelings, and fast action in emergency situations, we investigate if wireless technology is necessary to satisfy these needs.

### 3.2 Is It Necessary That Mobile Solutions for Diabetics Remotely Monitored Be Wireless?

Many researchers believe that a mobile response based on wireless technology would best fit the needs of diabetes patients cared of outside hospitals. Hoise [22], for instance, shows that mobile telemedicine aims to integrate wireless communications for different healthcare scenarios among which monitoring people suffering from diabetes. Market analysts predict wireless medical devices will find a market niche among others for people who suffer from a chronic disease such as asthma or diabetes [16]. "By the year 2020, the use of mobile computing in health care will extend average life spans by 20 to 25 years", one of the reasons for that optimistic forecasting being the virtual control of diabetes “through wireless monitoring and corrective-action devices, which will automatically adjust insulin levels without the patient even knowing" [3].

Advances in wireless and Internet technology made already possible the developing of new healthcare services, among which the wirelessly monitoring and the disease management of diabetes patients at home [34]. Thus, *WellMed Inc.* from the US developed a wireless application allowing patients to access their health information instantly, contact physicians via e-mail and fax machines, and receive critical information regarding their health insurance [12]. *SmartMeds.com* and *AT&T Wireless* from the US have developed a joint project able to remind patients to take the prescribed medication, call for prescription refills and deliver personalized information regarding patients' diseases, conditions, and medications [12, 58]. Patients, in their turn, must confirm wirelessly that they followed the required medication anytime they were reminded to take it.

An application developed by *IMetrikus Company* from the US gives today's diabetics the possibility to perform self-tests and enter their results through Web. The next step will consist of connecting glucose monitoring devices to the wireless phones and that is said to eliminate the necessity for Internet access as well as the typing errors. The application would also be capable of alerting patients such as for going to an emergency room or calling the doctor if readings go beyond a certain threshold [55].

If the diabetics are very ill or elderly taking and interpreting readings may be a big problem leading even to life threatening situations [17]. Consequently the approach would be with wireless technologies allowing independent readings and sending of the data remotely to the healthcare system because "people are often confused by device readings; technology never is", according to Edwards [17].

Significant efforts in the direction of remote monitoring of patients have been developed in Europe in recent years. Thus, Maglaveras et al. [32] describe a generic contact center able to handle problems regarding remote home care. Authors show that the application "proves the necessity for restructuring the medical knowledge for education delivery to the patient". Following the implementation of a three-year project which “received £160,000 funding from the *British Engineering and Physical Sciences Research Council*" [54], British doctors would be able to monitor remotely the health condition of their patients by receiving various data gathered by a single device and then sent through the regular mobile phone. Bludau [4] reports about a platform based on medical Bluetooth enabled sensors and using a GSM/UMTS telecommunication system to monitor in real-time patients at home by physicians at the hospital. The patient side includes modular sensors for measuring simple but vital parameters such as blood pressure, pulse rate, temperature, and oxygen saturation. *Arbonaut*, from Finland, and *Virtual Medical World Solutions*, from UK, have been trying to set a telemedicine platform for continuous monitoring of vital parameters. This would be addressed to patients with a "stable medical condition that allows a near normal life but may suddenly deteriorate and put life at risk." The project received EUR 1.7 million funding from European Commission for Telecare-project [44].

Our view is in concordance with most of the referred studies and research projects. Thus we believe that ***for most of the above-identified diabetics' needs, wireless technology would be the only***

***one able to provide the required features***. Fostering the patients' self-confidence and safety feeling, realizing a virtual permanent connection with nurses and doctors, alerting the healthcare system when some parameters such as blood glucose exceed the normal limits, and requiring for assistance and fast intervention in emergency situations cannot be conceived without the existence of a wireless connection between the patient and the healthcare system. However, ***some other features*** such as the constant monitoring by reminding to take the prescribed medication, follow the diet set by the doctors, or perform glucose self-tests at the required timing ***can be fulfilled by a mobile but not wireless application***. In order to not overload the wireless network and keep the costs low, it is reasonable to implant the latter functions in the patients' mobile devices. Wireless technology should be used only for the remotely contacting of the healthcare personnel, for out-of-range situations, alerts, and emergency functions.

After drawing the conclusion that a combination of wireless and mobile but non-wireless solutions would best meet diabetics' needs while remotely monitored, a subsequent questions is about the most suitable device.

### 3.3 What Type of Handheld Device Would Be Appropriate for the Remote-Care of Diabetics?

From the above discussion it appears that such a mobile device must have several functions. Most of them are "reminding" functions that do not need wireless capabilities:

- to perform glucose or other self-tests (blood pressure, weight, etc.);
- to take the prescribed drugs;
- to follow a certain diet;
- of the scheduled visits of the home care nurse; and,
- of the appointments with a family doctor or endocrinologist.

It is reasonable for the device to have memory and be programmable and customizable so as to host all these "reminding" capabilities. As an advanced feature, such a device could connect or be integrated to/with the glucose meter so as to capture the blood readings directly.

Other functions like sending alerts to nurses and doctors, receiving critical feedback from the healthcare and, especially, contacting healthcare in emergency situations require wireless access. These functions would necessitate a simple pager-like device with wireless capabilities. As an advanced feature, such a device may even be linked to the wired phone network in order to increase reliability and decrease communication costs when the patient is in a static location.

Consequently, the most suitable device for remote monitoring of diabetics would be a simple and cheap specific device with basic built-in functions for reminding. This device would also have wireless capabilities for two-way communications when alert or emergency situations require that. In order to be easy to use by all patients irrespective of their age, condition, and skills, the device should be kept as simple as possible. Patient age or technical skills should not be an obstacle in using of such devices due to the possibility of customization allowing various combinations of text and voice input and output according to Bludau [4]. However, the same author shows that special care should be taken with innovative technical equipment. This must be simple and robust in order to gain users' confidence by faultless work.

## 4. Proposed Solution for Wireless Remote Monitoring of Diabetics

Since, as discussed above, wireless technology seems to be the most appropriate approach for the home care disease management of diabetics, this section suggests a simple solution suitable for large categories of patients who need constant monitoring.

Choosing the right technology and implementation strategy for such an application is very important since statistics show that 45% of the projects involving the deployment of IT in healthcare failed to produce the expected benefits [34]. According to the *Information Technology Association of Canada for Ontario*

*(www.itacontario.com)*, any IT implementation in the medical sector must be physician-led, and enhance healthcare delivery in small incremental steps. Some practicing physicians such as Silver [51] strongly advocate for running of pilot projects in diabetes disease management because that would lead not only to improving of health state of but also to a better acceptance of IT in this sensitive sector.

### 4.1 Scope & Principle of a Solution for Diabetics' Remote Monitoring

The main scope of the suggested solution is to make the diabetes patients both live a life as normal and active as possible and feel 24 hours a day under the constant care of doctors and nurses. This scope could be reached by a combination of mobile and wireless monitoring, reminding, alerts and emergency responses. Ralinmed [45] reports of a similar program based on guidelines from the *American Diabetes Association* and having as outcomes, among others:

- reducing of emergency room visits and hospital admissions;
- reducing the number of days missed from work and/or school;
- improving participating patients' and physicians' satisfaction; and,
- improving patients' quality of life.

The principle of the proposed solution is to allow diabetics monitored remotely to live a usual and dynamic life as long as they follow the prescribed medication and diet on one hand, and their self-test results stay within the limits defined for them by the doctors or nurses on the other hand. If, because of patients' fault or due to other causes such as inappropriate meals, drinks, physical effort or stress, patients' readings go beyond the limits for a number of times, as set by the doctors, then a progressive alert system is triggered. Depending on the drift from the normal situation, the system may involve the home care nurse, family doctor, endocrinologist, or even the emergency response service as shown in the Figure 1 below. Alternately, patients can call directly the home care personnel or the emergency services if they feel necessary.

### 4.2 Key Components & Functions

The proposed system would be operated and managed by the local homecare organization in charge with caring of diabetics out of hospitals. As key components, the system would comprise patients' devices and a central server accessible remotely by homecare personnel, doctors, and endocrinologists as well as by the emergency response services as shown by the Figure 2 below. Main functions of the system are briefly described below.

***Constant monitoring.*** Patients would perform their regular glucose self-tests and other tests indicated by doctors and nurses. If the results are between the normal limits set individually for each patient, no action will be triggered. As, presumably, many patients would be elder people or in a condition making difficult to type through a handheld device, data entering could be voice messages followed by converting to text. Such applications have already been pioneered in the medical world [46] and cell phones with voice dialing are already a reality [38]. In a technologically more advanced approach patients' mobile devices would be connected or integrated with the glucose monitors [3, 17].

***Reminding.*** The handheld device would remind patients to take the prescribed pills, perform tests such as glucose, blood pressure, or weight, to start or stop various medications, etc. This function could be easily programmed and implemented by a visual and/or audible signal or even by vibrations already present in cell phone technology. In a more advanced approach, patients would confirm complying with the reminder by simply pushing a button.

***Sending alerts.*** If some of the self-test parameters are beyond the limits, the patient or the device itself would send an wireless alert to the local homecare server. The server, that would have pre-stored patients' profiles, would manage the alerts by notifying the responsible home care personnel (e.g. nurses) first. A gradual approach should be then undertaken depending on the gravity of the situation.

***Instant consulting.*** Irrespective of their readings and health state, patients may want to contact a nurse or a physician for an instant consultation or for an appointment. In order to facilitate and prioritise patients' calls compared to other incoming calls, the service should be provided again through the local homecare server.

***Emergency response.*** The handheld device should also provide the possibility to call for an emergency if patients feel necessary to do so. The local server, able to identify the patient identity, would reroute the call to the emergency response while also notifying the patients' responsible nurses and physicians.

From the patients' perspective, implementing the functions as described above would make patients feel under constant care as virtually having at least a nurse by them all the time. From the healthcare's point of view, due to the gradual approach of the system, the serious and emergency interventions would presumably be very rare so the doctors and nurses' workload is much reduced, especially for routine low-level activities [17, 24]. *HomMed LLC* reports "monitoring devices reduce the need for emergency-room visits by 99% and hospitalizations by 92%" [17].

All the above selective wireless communications would not pose major issues in terms of privacy, security, or connectivity. They would have the current standard of cell phone calls. Furthermore, it is unlikely that patients or healthcare system would be affected by the interception of uncritical fragments of information such as above. Connectivity is not a problem as well since most of the above functions do not require immediate action neither from the central system nor from the patients.

## 5. The Business Case for Diabetes Management

After discussing the principle and key functions of a solution for remote care of diabetics an important issue is to examine the business aspects. Health-care agencies spend $98 billion a year to care for the 16 million Americans with diabetes, according to the *Centers for Disease Control* [17]. Statistics of diabetics' costs in the US presented in Table 2 show that an important segment of patients with diabetes are treated out of hospitals. This would be the target market for the system of self-management by remote monitoring of diabetics.

Remote monitoring of diabetics' conditions and adopting a pro-active attitude would draw immediate and potential savings. The two areas of savings are discussed next.

### 5.1 Immediate Savings

The target of keeping patients in ambulatory treatment would bring huge savings to the system especially because of hospitals dealing only with truly acute cases.

***Reduced hospitalization.*** Considering the daily cost of hospitalization, even shortening the period of acute care for a patient would generate significant savings. Moore and Wesson [34] show that hospitalization in the UK costs £3000 per bed daily. In Canada "each round trip to the ER (emergency room) costs the health system almost $1,000 and about $60 from the patient's own pocket" [63]. Overall, researches suggest that hospitalizing patients is becoming a less and less reasonable approach because of hospital bed and practitioner shortages and, above all, of financial reasons.

***Reduced cost of primary care.*** Avoiding unnecessary patient appointments would save time and money for family doctors and clinicians. Patients would be scheduled for consultation only when strictly needed.

***Reduced cost of home care.*** Similarly, home care personnel will save time and money by not having to frequently visit all patients at home. A research conducted in the U.K. by Moore and Wesson [34] has shown that 80% of community nurses' time is consumed with five types of diseases: pressure ulcers, incontinence, cancer, diabetes, and elderly care. By utilizing remote monitoring, direct

dialogue with patients will shift to remote communications without diminishing the patients' quality of care.

***Reduced absenteeism.*** In 1997, diabetes generated a loss of nearly "14 million disability days and an average of 8.3 days off from work compared with 1.7 days off for people without diabetes or other chronic conditions" in the US [27]. Studies showed that disease management helping diabetic patients manage their blood sugar decreased the cost for employers from $115 per employee and month to $24 per employee and month [27]. Savings resulted primarily because employees with improved glycemic control had lower rates of both absenteeism and restricted work activity. Hence, the increasing interest by employers in disease management.

## 5.2 Potential Savings

Besides direct costs, hospitalization is undesirable for diabetes patients because of physical, psychological, and social reasons. Long-term immobile patients have shown bed sores, muscle atrophy, reduced circulation, increased depression, and agitation [34]. On the contrary, if patients can be cared out of hospitals and live normally while, at the same time, the healthcare addresses their disease, the psychological state would improve. Continuous monitoring of diabetics' health state would prevent unexpected deterioration of patients' condition due to faults or unpredicted factors, such as:

- discontinuing medication;
- altering medication pattern;
- uncommon side effects of medication;
- bad combination of medication with food or effort;
- weather influences.

Consequently, this would avoid late interventions by medical personnel and diminish the occurrence of dangerous complications of diabetes such as heart attacks, eye, kidney, or vascular diseases that result in dire consequences for patient, society, and the healthcare system [13, 14, 51, 61]. A trial involving 3,867 people with type 2 diabetes in 23 clinics around the UK showed that an intensive policy of keeping diabetes under control costs an extra £140 per year per patient, but about £100 of that amount would be saved by reducing diabetes' complications [30].

Patient education is also an important indirect issue. Involving the patients actively makes them become more responsible and learn to adjust their own care in terms of diet, medication, physical efforts, etc. in order to prevent the deterioration of their medical condition [4, 29].

## 5.3 Costs

Several researchers have shown that costs of a remote monitoring of diabetes solution would be very low, compared to the immediate and long-term savings depicted above. "It costs $5 to $10 per day to equip a patient with a remote-monitoring system while an emergency-room visit costs an average of $900" [17]. A remote monitoring device for diabetes "will cost about as much as a single trip to the local emergency room" [16].

Researchers also say that people would be willing to support part of the costs. "People who have diseases such as asthma and diabetes are more motivated than the rest of the population and more likely to pay for these devices (…) and you would think insurance companies would see the value, especially if they can help prevent costly hospitalization" [16]. Other opinions suggest patients' devices could be supported by the healthcare system since the savings would exceed the costs by far. Furthermore, most of the exchange of information in the remote-monitoring system would be fully automated and that would reduce cost with work and system maintenance. The investment would presumably be recuperated shortly by the healthcare system by avoiding expensive hospitalizations and critical medical interventions, as showed above.

## 6. Conclusions and Future Development

Diabetes is a chronic disease affecting hundreds of millions of people around the world, regardless of age, gender, socio-economic, cultural, and educational background [9]. For some segments of diabetics it is possible to treat this disease out of hospitals while living an active life. A combination of psychical, social and, especially, cost aspects makes appropriate the concept of self-management by remote care.

Wireless technology can be harnessed in state-of-the-art applications facilitating self-management of diabetes. Key aspects of such applications include reminding patients about medication and diet, blood glucose monitoring with configurable alarms and alerts, as well as remote consultation and emergency intervention. Such applications can yield a higher percentage of stabilized blood glucose levels in diabetes patients, and thereby reduce both short and long-term complications together with facilitating compliance and further patient education. At the same time, the quality of care is enhanced, care is extended to more patients, and the cost of healthcare is reduced through various direct and indirect savings.

Basic but fully working mobile commerce applications involving patients would increase the confidence in mobile and wireless technology applied in healthcare in general. This is expected to have a push effect for the other actors of the healthcare system thus convincing "the conservative health system that mobicare makes sense" [59]. New dimensions of the remote monitoring and care could be acquired in the future if the multimedia messaging services able to embed voice, text, and pictures in a single message would confirm the expectations. On the other hand, a system as described in this paper has the potential to integrate within the Canada-wide *Electronic Health Record* system expected to be in place by 2010 [6].

Ultimately, this is an affordable step towards the ideal system foreseen by some researchers where all segments of the healthcare system (hospitalists, clinicians, family doctors, home care personnel, insurance companies, pharmacists and, last but not least, patients) would be able to echoing timelessly and in a mobile context information and communication with the same goal: better serving the patients with less human and financial efforts.

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## Tables

**Table 1.** Value of wireless technology in addressing diabetics' needs

| Catego | Ite | Activity | P | V |
|---|---|---|---|---|

| ry | m | | atient Need | alue of mobile solution |
|---|---|---|---|---|
| **Behavior modification** | Consulting | Immediate communication with health care practitioner (especially during incompliance or abnormal indicators) | High | High |
| | Education | Reminder of information session | High | Low |
| | | Notification of external sources of information of interest | Low | Low |
| **Monitoring** | Blood Glucose | Readings performed | High | High |
| | | Data logging | High | High |
| | | Notification of critical or near-critical levels to health care providers | High | High |
| | Blood Pressure | Readings performed | Medium | Medium |
| | | Data logging | Medium | Medium |
| | | Notification of critical or near-critical levels to health care providers | Medium | High |
| | Weight | Readings performed | Low | Low |
| | | Data logging | Medium | Low |
| | | Notification of critical or near-critical levels to health care providers | Low | Low |
| **Compliance** | Diet | Recording of meals consumed | High | High |
| | | Retrieval of diet plan | High | High |
| | | Notification of diet plan incompliance | High | High |
| | Exercise | Recording of activity | Medium | Medium |
| | | Notification of physical exercise plan incompliance | H | L |

| | | | | |
|---|---|---|---|---|
| | | | igh | ow |
| | Medication | Reminder to take prescribed drugs | High | High |
| | | Recording of drugs taken | High | High |
| | | Notification of drug plan incompliance | High | High |
| | Monitoring | Reminder to take reading | High | High |
| | | Recording of data | High | High |

**Table 2.** Statistics of diabetes cases, place of treatment, and outcomes in the US

| Statistic | Total count |
|---|---|
| **Ambulatory care** [11] | |
| Number of visits to office-based physicians | 26.9 million (2001) |
| Number of hospital outpatient department visits | 2.6 million (2001) |
| **Hospital inpatient care** [20] | |
| Number of discharges | 562,000 (2001) |
| Average length of stay | 4.9 days (2001) |
| **Home health care** [8] | |
| Number of current patients with diabetes as primary diagnosis | 106,400 (2000) |
| Percent of current patients with diabetes as primary diagnosis | 7.9 (2000) |
| **Mortality** [2] | |
| Number of deaths | 71,372 (2001) |
| Deaths per 100,000 population | 25.1 (2001) |
| Cause of death rank | 6 (2001) |

## Figures

**Figure 1.** Schema of selective alerts triggered by a remotely monitored diabetic

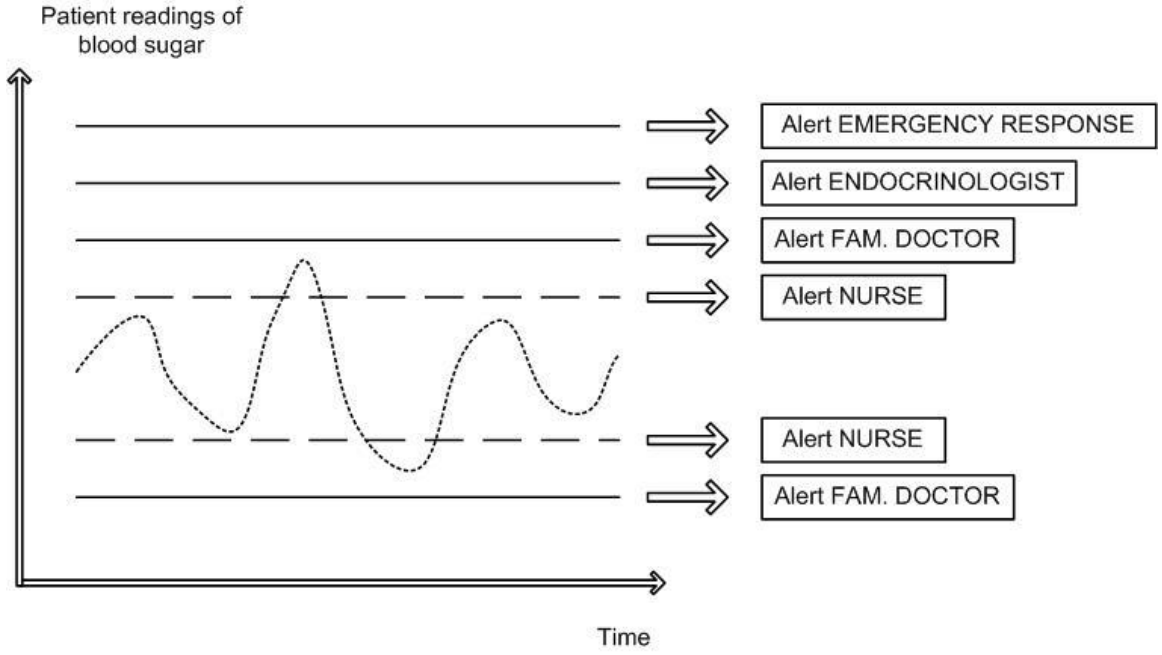


**Figure 2.** System of remote monitoring of diabetics