M-healthcare for patient self-management: a case for diabetics

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Abstract: Disease management facilitated through information technology could mean a step forward towards a more effective and efficient care of patients afflicted with chronic illnesses. Focussing on diabetes, the paper explores the value proposition of wireless technology in enhancing patient self-management and quality of life. Diabetics' non-compliance with prescribed treatment plans mandates the adoption of advanced tools that can support patients through automated functions (e.g., notification reminders for taking medication), decision-support (e.g., analysis of self-test data and feedback), and anytime/anywhere communication and intervention capability (e.g., emergency consultation by healthcare practitioner). A cost-benefit analysis for the mobile self-management of diabetics suggests time and financial savings for both patients and the healthcare providers.

Keywords: disease management; self-management; diabetes management; mobile-healthcare; m-health; e-health; wireless communication; chronic illness; home care.

Reference to this paper should be made as follows: Cocosila, M., Coursaris, C. and Yuan, Y. (2004) 'M-healthcare for patient self-management: a case for diabetics', *Int. J. Electronic Healthcare*, Vol. 1, No. 2, pp.221–241.

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1 Introduction

Modern healthcare faces numerous unprecedented challenges: an aging population, increasing incidence of chronic illnesses, the need to cope with people's tendency towards mobility and an active lifestyle, as well as a limitation of funds resulting in a shortage of hospital beds and healthcare personnel. In addition, 'due to changes in government policy, severe competition and advancement in information technology, the healthcare industry is unstable, highly agitated and very competitive' (Siau, Southard and Hong, 2002). Overall, there is a contradiction between the increasing requirement for improved quality of care for patients and the availability of healthcare resources (Cowling, Newman and Leigh, 1999).

Disease management of some chronic illnesses could be one approach in enhancing quality of care for patients and, consequently, improving their quality of life, while addressing the challenges of today's healthcare. 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' (Landis *et al.*, 2003a). Important components of the disease management paradigm include collaboration between physicians and support-service providers, patient self-management education (primary prevention, behaviour modification programmes, compliance, and monitoring), outcomes measurement, evaluation, management and communication between patient, physician, health plan and ancillary for reporting and feedback. Out of these, self-management is arguably the most critical component in the success of any patient-centric healthcare solution, as it requires the active collaboration of the patient. Furthermore, to enhance the effectiveness and efficiency of self-management initiatives, technology is considered as the enabler for such patient-centric solutions.

Diabetes is a chronic disease that 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 lifestyle changes, the incidence of diabetes has been rapidly increasing (Moore and Wesson, 2002). It was estimated that diabetes costs Canada and the USA approximately $9 and $98 billion per year respectively (Edwards, 2002; Health Canada, 2003). This rise, 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 with the use of mobile and wireless communication technology.

This paper discusses the value proposition of mobile healthcare (m-healthcare) enabled by wireless technology to day-to-day diabetes management for patients cared

outside a clinical environment, with the patients' active involvement. In doing so, we organise the remaining paper as follows. In Section 2, an overview of disease management and self-management is provided along with the evidence that such programmes improve the patients' condition and quality of life, while considering the advantage of using wireless technology to enhance such programmes. In Section 3, by exploring diabetes and diabetics' needs, the requirements of a self-management programme tailored to diabetics are discussed. In Section 4, a system for mobile self-management of diabetics is proposed. In Section 5, the business case of cost/benefit analysis for mobile diabetes management from both the patients' and the healthcare system's perspective is discussed. Finally, conclusions and further research directions are presented in Section 6.

2 M-healthcare and self-management

Due to its clear advantages over traditional models of acute care, disease management is becoming increasingly attractive in the healthcare world (Moran, 1999). Studies suggest that disease management is an effective approach in improving the Quality of Life (i.e., individual's mental and physical state) for people with certain chronic conditions. A study performed in the USA on a representative sample of 693 diabetics, who were in a nurse-mediated disease management programme for at least 90 days, showed that 20% of the patients had a significant improvement in *Mental Component Summary Score* and another 59% remained at the same level. Also, 30% of the patients showed a clinically significant improvement in *Physical Component Summary Score* and for another 51% the level remained stable (Landis *et al.*, 2003b). In a similar study, 18,262 patients living with chronic conditions were enrolled for at least 180 days in a disease management programme and were subsequently assessed for changes in mental and physical quality of life. Patients took part in one of four disease management programmes: chronic obstructive pulmonary disease, coronary artery disease, diabetes, or heart failure. Results found that 84% of patients had a clinically significant increase or remained clinically stable in their mental health score. Also 86% of the patients had a clinically significant improvement in their physical score or remained clinically stable. The researchers concluded that disease management programmes could improve the Quality of Life for patients with chronic conditions. Moreover, the improvement in physical condition is higher than that in mental health (Walker *et al.*, 2002).

Research has also shown that self-management educational interventions may lead to positive outcomes for patients' conditions across various diseases associated with high incidence and treatment cost such as chronic heart failure, asthma, diabetes, and hypertension (Celler, Lovell and Basilakis, 2003; Chin, 2002; Wolf, Guevara and Grum, *et al.*, 2002). Therefore, it seems reasonable to transfer the responsibility of monitoring indicator levels to the patients, thereby improving their mobility, education, active participation, responsive attitude, and self-confidence, while at the same time contributing to the overall efficiency of the healthcare system (Rohm and Rohm Jr., 2002). Last but not least, self-management could help in enhancing behaviour modification and treatment plan compliance through a combination of education and intervention.

Despite its advantages, the existing approach of self-management poses several challenges:

- Difficulty in tracking patient compliance with prescribed treatment plan (e.g., incomplete diaries) due to the current self-management system's inability to support the patient in this task or the patient's disorganised nature.
- Uncertainty in patients' decision-making due to the absence of a decision support system. Education, which is mostly conducted offline, is a passive form of decision-making support that is constrained by the patient's cognitive ability (e.g., a patient has to remember what the various blood glucose levels imply and remember to act accordingly in various scenarios after a self-test).
- Inability to maintain a constant connection between the patient and the healthcare system due to the inherent off-line link between all parties (e.g., in case of an emergency while being mobile, it is difficult for a patient to receive immediate assistance).
- Untimely sharing of information due to the time lag involved between data collection and patient-physician consultation.

Furthermore, every patient responds differently to a particular chronic disease (i.e., symptoms and condition progress). While patients are equipped with knowledge gained through education sessions and consultations, applying lessons learned can be quite challenging, due to a patient's possible disorganised nature, unstructured lifestyle, inadequate decision-making skills, and/or mobility (i.e., may not be reachable, available, or capable to attend appointments or perform self-tests). In the absence of advanced tools for patient compliance with prescribed treatment plans, these factors hinder the success of self-management programmes.

Today information technology can significantly enhance healthcare in general (Bergeron and Bailin, 1999) and disease management and self-management in particular by providing a more coordinated and proactive approach to managing chronic illness (First Consulting Group, 2004). The idea of e-health and m-health (Coursaris, 2003; Hoise, 1999), among other means, could make possible the remote care of patients (i.e., out of hospitals) that features both enhanced quality of care and reduced costs. Mobile solutions enabled by wireless technology may help address the barriers to self-management through automation, analysis and decision support. The same system could address general healthcare challenges as highlighted next (Hatzakis Jr. *et al.*, 2003):

Access: Wireless technology allows patient access to healthcare data and services without time or location constraints. Conversely, the patient can be reached by the healthcare system (e.g., practitioners, computers) any time and any place, if necessary. In contrast to the wired internet, which is able to only reach the place, wireless technology goes farther by being able to reach the person.

Quality: Wireless technology could equip patients with information of better quality and a more efficient and effective communication capability with the healthcare system. Patients would be better informed and educated, more active, thus improving their self-efficacy, whilst having the peace of mind that expert (third party) assistance is readily available. This matches the strong interest of today's healthcare providers and managers (Martin, Yen and Tan, 2002).

Value: The healthcare sector would realise financial savings by preventing unnecessary patient complications that would otherwise translate in costs for the primary and acute care. Homecare would realise operational (e.g., time) and financial savings, and patients would have the freedom to live a normal life, integrated in the society, without absenteeism from work or school.

Diabetes is one of the possible chronic diseases that could be addressed by a patient self-management disease programme enhanced through the use of wireless technology. It should be noted that this disease is one of the most serious cost generators in healthcare (Chin, 2002). Furthermore, 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 diabetes, especially in the Western Hemisphere, will yield the existing health resources and methods insufficient (Moore and Wesson, 2002). 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 symptoms.

3 Self-management 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 (CDC, 2003b). Estimates of diabetics in the USA are over 18 million (ADA, 2003); in Canada, more than 2 million (CDA, 2001); in Europe, over 30 million (Onraed, 2002); and in the Western Pacific, 30 million (WHO, 2001). Approximately one in ten people is diagnosed with diabetes, while another two out of ten are at risk and classified as 'pre-diabetes' (ADA, 2003; WHO, 2001). 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 (ADA, 2004). 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 are consequent of patient non-compliance with the prescribed instructions of the physician and other experts (e.g., dietician). This is an area of growing concern for the healthcare industry. Thus, Section 3 attempts to provide further insight on the issue of non-compliance.

3.1 Patient responsibility in diabetes self-management

By understanding patients' needs after the initial diagnosis of diabetes, patient responsibility in self-management can be clearly identified (information in this section is based on ADA, 2003). Diabetics are classified in four categories, Type 1 (characterised 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. Thus, by examining a typical Type 2 patient's needs, an understanding of the needs for the remaining diabetics will also be facilitated.

The primary goal of all diabetic treatments is the stabilisation of blood sugar level that may vary as a result of many potential factors, such as stress and diet. Type 2 diabetes may be controlled by a change in lifestyle (such as physical exercise) and/or in diet. While this is an area where the patient is in complete control, non-compliance with suggested lifestyle changes is the most prominent problem among diabetics. In the event when exercise and diet do not restore blood sugar levels to normal, oral agents (i.e., specific pharmaceutical 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. Adding to the risks associated with diabetes, unlike Type 1, Type 2 diabetics may not show any symptoms even though they can be undiagnosed cases of diabetes.

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 capable (e.g., handicap or lack of necessary equipment) and/or responsible (e.g., negligent) in monitoring their indicators regularly, or simply ignore the data and/or blame it to external conditions such as faulty readings.

In summary, diabetics are in need of and ultimately responsible for, stabilising their blood glucose levels and in doing so they invoke one or more of the following: exercise, diet, oral agents, insulin, and self-monitoring of blood glucose levels. The main issue with all of the above requirements is non-compliance. Non-compliance may occur due to a resistance to change or simply lack of education. Thus, behaviour modification is often critical among diabetics, and the use of information technology in disease management programmes may facilitate this adaptation.

3.2 The need for information technology in diabetes self-management

The discussion on this point has included the concept of disease management and the diabetics' responsibility. This section explores the effectiveness of diabetes self-management and the justification of using information technology in support of this. In doing so, a literature review of published studies is provided. In addition, Table 1 outlines the key components of diabetes self-management along with various activities and the value that mobility and wireless technology bring to a potential solution addressing the needed activities.

Several studies have examined the issue of patients' non-compliance with prescribed plans-of-care (Burge, 2002; Diehl *et al.*, 1985; Kuo *et al.*, 2003; Lutfey and Wishner, 1999; Paes *et al.*, 1997; Ruggiero *et al.*, 1990; Sulway *et al.*, 1980; Wing *et al.*, 1985). Results suggest that Self-Monitoring of Blood Glucose (SMBG) improves a patient's compliance, and it also has a positive effect on a diabetic's efforts to stabilise his/her blood glucose levels. Furthermore, there is extensive research that investigates the influence of variables such as self-management competence and information technology on a patient's blood glucose level stabilisation (Skinner and Hampson, 2001; Wysocki *et al.*, 2003). Representative studies relevant to diabetes self-management are presented next.

Self-management training in Type 2 diabetes was shown to be effective, particularly in the short term, in improving the frequency and accuracy of SMBG, self-reported dietary habits, glycemic control, and knowledge (Norris *et al.*, 2001; 2002). However,

quality of care provided to the vast majority of diabetics is problematic due to the current prevalence of the acute model of care (Glasgow *et al.*, 2001). Effective diabetes management programmes should be patient-centric and encompass the following characteristics:

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

Table 1 Value of mobile and wireless technology in addressing diabetics' needs

Category	*Item*	*Activity*	*Patient Need*	*Value of Mobile Solution*	*Value of Wireless Solution*
Behaviour modification	Consulting	Immediate communication with healthcare practitioner (especially during non-compliance or abnormal indicators)	High	High	High
	Education	Reminder of information session	High	Low	Low
		Notification of external sources of information of interest	Low	Low	Low
Monitoring	Blood Glucose	Readings performed	High	High	Low
		Data logging	High	High	Medium
		Notification of critical or near-critical levels to healthcare providers	High	High	High
	Blood Pressure	Readings performed	Medium	Medium	Low
		Data logging	Medium	Medium	Medium
		Notification of critical or near-critical levels to healthcare providers	Medium	Medium	Medium
	Weight	Readings performed	Low	Low	Low
		Data logging	Medium	Low	Low
		Notification of critical or near-critical levels to healthcare providers	Low	Low	Low
Compliance	Diet	Retrieval of diet plan	High	High	Low
		Recording of meals consumed	High	High	Medium
		Notification of diet plan non-compliance	High	High	High
	Exercise	Recording of activity	Medium	Medium	Low
		Notification of physical exercise plan non-compliance	High	Low	Low
	Medication	Reminder to take prescribed drugs	High	High	Low
		Recording of drugs taken	High	High	Medium
		Notification of drug plan non-compliance	High	High	High
	Monitoring	Reminder to take reading	High	High	Low
		Recording of data	High	High	Medium

The above findings are complemented by the demonstrated clinical effectiveness of Medical Nutrition Therapy in diabetes management (Pastors *et al.*, 2002). 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, counselling, and the use of nutrition supplements.

Another component of disease management, SMBG, has been shown to enhance self-management effectiveness. There is a positive relationship between rigorous blood glucose monitoring at home and improved glycemic control (Burge, 2002), and SMBG is important in improving metabolic control if made part of patient's self-management (Franciosi *et al.*, 2001; Karter *et al.*, 2001).

The above studies support the idea that self-management is an effective approach in stabilising a patient's blood glucose levels, which subsequently reduces the incidence of further complications (The Writing Team for the Diabetes Control and Complications Trial/Epidemiology of Diabetes Interventions and Complications Research Group, 2003), and improves the patient's quality of life (AHRQ, 2000). It is important for healthcare providers to consider the patient's beliefs about the disease and the treatment and to work together with the patient in developing a realistic plan that, if followed, will have the desired effects. Intervention is effective in diabetes management but it needs to be patient-centric (Renders *et al.*, 2001).

Having demonstrated that diabetes management programmes are effective, the next question is whether information technology has a place in this environment for further improvement. First, electronic transmission of blood glucose levels at regular intervals, replacing the need for a clinic visit, has been shown to yield similar levels of glucose control and subsequent incidence of complications to those of patients receiving regular standard care (Chase *et al.*, 2003). Therefore, patients need not make frequent visits, consequently saving healthcare providers' time. Furthermore, personalised 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 above-mentioned studies have shown that the combination of disease management programmes, self-management training, education, and the use of information technology can improve diabetics' health and quality of life (by fostering self-efficacy and reducing the incidence of health-related complications), while at the same time benefiting the healthcare system. Based on the information found in these studies, Table 1 presents the value of wireless technology in addressing diabetics' needs, while the drivers for using wireless technology in diabetes management include the following:

- enhanced mobility of patients
- constant reinforcement of patient self-compliance
- continuous monitoring of patients' health
- immediate access to critical services for patients.

A key issue with diabetes management is that the required treatment plan varies among patients depending on their characteristics (Nash, 2001). Therefore, mass personalisation, (not in its usual marketing context) where different services are tailored for and used differently by each patient, is a key success factor in developing a system that utilises wireless technology.

4 Proposed system for the mobile self-management of diabetics

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 information technology in healthcare failed to produce the expected benefits (Moore and Wesson, 2002). According to the *Information Technology Association of Canada for Ontario (www.itacontario.com)*, any such implementation in the medical sector must be physician-led, and enhance healthcare delivery in small incremental steps. To increase the likelihood of a successful implementation, the scope, key system components, functionality, and enabling technology need to be clearly defined.

4.1 Scope

The main scope of the suggested solution is to make diabetics live a life as normal and active as possible, as well as to provide a sense of constant care by healthcare practitioners. This scope could be reached by a combination of mobile and wireless applications. A similar programme based on guidelines from the *American Diabetes Association* has as outcomes, among others, the following (Ralinmed, 2003):

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

4.2 Key system components

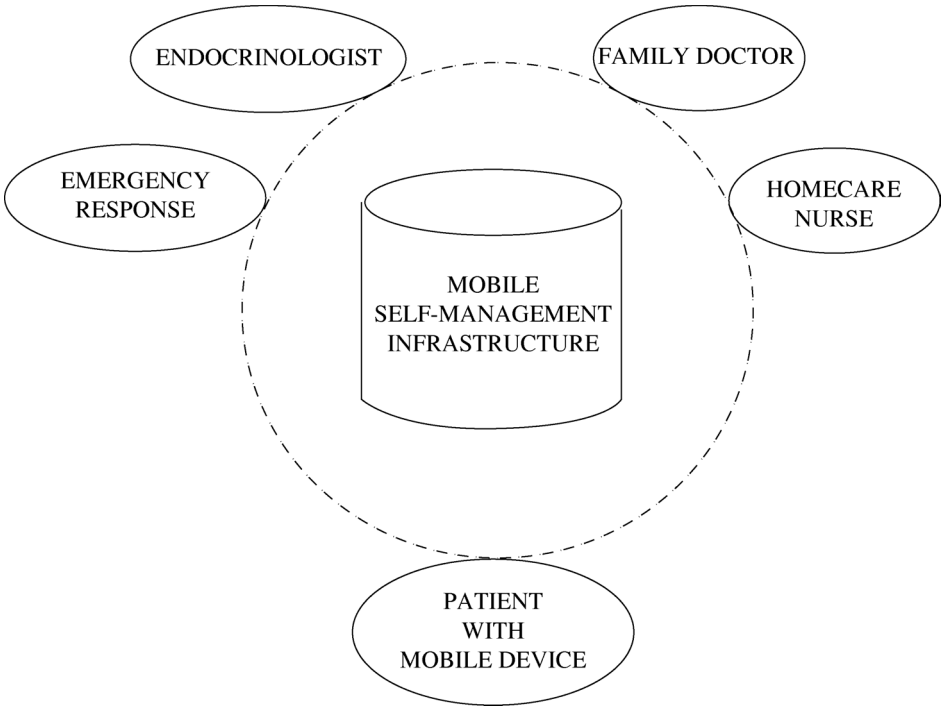
The proposed system would be operated and managed by the healthcare organisation in charge with caring for diabetics out of hospitals. In Canada, for instance, this organisation would be the local home care also providing for the patients in need the necessary links to the primary care and acute care. As key components, the system would comprise patients' devices and a mobile self-management infrastructure accessed remotely, through multiple channels, by homecare personnel, doctors, and endocrinologists as well as by the emergency response services as shown in Figure 1. The system would allow relevant patient data storage and distribution, based on prior patient segmentation and on the customised treatment set by doctors for each patient.

4.3 Key system functions

While extensive system functionality can be supported by technology currently available, the key functions of a mobile and wireless self-management system are briefly described next.

Constant monitoring: Patients would perform their regular glucose self-tests and other tests indicated by doctors and nurses. Data would be stored either on the device or on a central server with the patient's profile and chart. Immediate feedback may be available based on the analysis of self-test results, recommending to the patient a course of action.

Figure 1 System of remote monitoring of diabetics

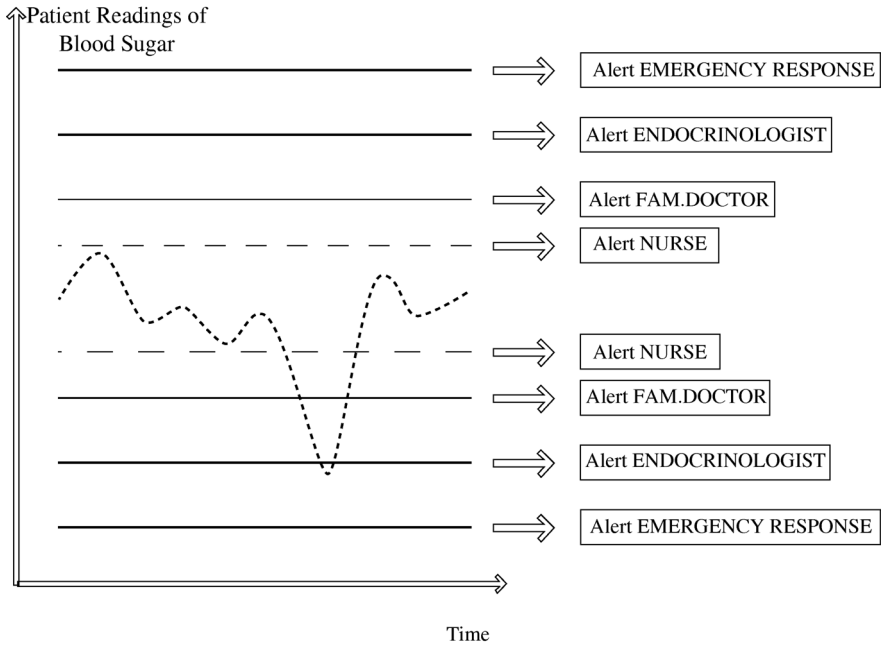


Reminding: The handheld device would remind patients of prescribed treatment plan actions, such as taking medication and performing self-tests among others. This function could easily be programmed and implemented by a visual and/or audible signal or even by vibrations already present in cell phone technology. In a more advanced approach, patients would confirm complying with the reminder, for example by simply pushing a button.

Sending alerts: If results from self-tests are between the normal limits set individually for each patient, no action will be triggered. Conversely, if readings go beyond specified health wellness limits, then a progressive alert system is triggered. Depending on the drift from the normal levels, the system may involve the home care nurse, family doctor, endocrinologist, or even the emergency response service as shown in Figure 2.

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 mobile self-management infrastructure. As many patients would be elder people or in a condition making it difficult to type through a handheld device, other possible technological approaches may be considered, one of these being the conversion of voice messages to text. Such applications have already been pioneered in the medical world (Rebentisch, 2002) and cell phones with voice dialling are already a reality (Nokia, 2003). In a technologically more advanced approach patients' mobile devices would be connected or integrated with the glucose monitors (Edwards, 2002).

Figure 2 Schema of selective alerts triggered by a remotely monitored diabetic



Emergency response: The handheld device should also provide the possibility to call for an emergency if patients feel necessary to do so. The mobile self-management infrastructure, able to identify the patient's identity, would reroute the call to the emergency response while also notifying nurses and physicians responsible for the patient.

As seen from above, the mobile self-management infrastructure would fulfil the functions of a call centre empowered by the internet and wireless technology. For increased efficiency most of the infrastructure's actions such as patient data storage and distribution, call rerouting, or messaging could be automated. Other functions, such as answering alerts or offering instant consultations would require the continuous presence of homecare personnel. Implementing these functions would make patients feel they are under constant care as virtually having at least a nurse with 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 would be significantly reduced, especially for routine low-level activities (Edwards, 2002; Karsten *et al.*, 2002). 'Monitoring devices reduce the need for emergency-room visits by 99% and hospitalisations by 92%. The systems haven't been in use long enough to produce detailed statistics, but two healthcare providers testing such technologies*, Nurses That Care* and *American Healthways*, agree that those figures seem reasonable' (Edwards, 2002).

4.4 Enabling technology

This section explores the appropriateness of utilising standalone mobile solutions or the ones enabled by wireless technology in addressing the information and communication

needs of diabetics. A distinction must be made here between *mobile* and *wireless*. Mobility does not necessitate wireless access, although it can be supported / enhanced through the latter. Mobile applications can accompany people in motion and function without the need for a network connection (e.g., wrist watch alarms). Wireless, on the other hand, implies the use of wireless networks for the enabling desired functions (e.g., receiving real time alert messages). Given this distinction, it is important to identify which needs be addressed by mobile and which ones by wireless solutions.

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 (i.e., utility) of the service required (Mennecke and Strader, 2003). The utility of supporting the self-management of diabetics can be seen in Table 1, where the most important activities are qualified in terms of the patient's need for each of them. These activities need to be continually supported by either a mobile or a wireless solution. Therefore, to justify which technology should be selected the criteria are location and urgency.

Mobile solutions could address the (planned or unplanned) changing location of a patient throughout the course of the day. Functions including reminders, self-tests, and data storage can be enabled through a mobile device without the need to access the internet. By utilising electronic devices for this purpose, there is significant potential in improving the quality of care for these patients, as shown earlier. However, in the event that a patient requires communication with or intervention by healthcare (e.g., notification of critical indicator levels to healthcare providers, emergency communication between patients and healthcare practitioners), regardless of location, a wireless solution is required. This segmentation and prioritisation of patients' conditions is necessary to prevent from overloading the system with unnecessary data. Consequently, the system would have improved efficiency in managing patients' uncommon conditions. Table 1 shows the relative suitability of each technology for the most important activities in the self-management of diabetics, while Table 2 lists new healthcare services made possible through advances in wireless and internet technology, among which are the wireless monitoring and the disease management of diabetes patients at home (Moore and Wesson, 2002).

Fostering the patients' self-confidence and perceived safety by realising a virtual permanent connection with nurses and doctors for consultation and fast intervention in emergency situations cannot be conceived as efficiently and effectively as with the combination of wireless (i.e., network enabled) and mobile (i.e., carried by person) solutions. Thus, a subsequent question arises regarding the identity of the most suitable device.

From the above discussion it appears that a mobile device intended for use in diabetes self-management should offer several functions so as to be like a 'portable' nurse. As mentioned earlier, most of the functions are 'reminders' that do not need a wireless connection. Therefore, it is reasonable for the device to have sufficient memory and be programmable and customisable so as to host all of these 'reminder' functions. 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, such as contacting healthcare practitioners in emergency situations, require remote two-way connections. This functionality may be achieved with several technologies. Programmable common or modified cell phones, wireless Personal Digital Assistants, or pagers are some of the options available. Devices provided with Bluetooth transmission capabilities and desktop or laptop computers using internet-based

applications are additional examples. It is worth mentioning that an information system such as *ProWellness*, which was pioneered in Europe with the scope of remotely managing several chronic diseases, initially focused on diabetes. Patients using *ProWellness* can record their disease management activities daily by means of a landline (i.e., wired) telephone or a mobile phone with the idea that 'careful self-care and good communication with the care team are essential for successful diabetes management' (ProWellness, 2004).

Table 2 Examples of implemented mobile / wireless applications for diabetes self-management

Author or Company	*Functionality*
WellMed (Conlin, 2000)	Patients can access wirelessly their health information instantly, contact physicians via e-mail and fax machines, and receive critical information regarding their health insurance.
SmartMeds.com and AT&T Wireless (Conlin, 2000; Wirelessnewsfactor, 2000)	Reminds patients to take prescribed medication, call for prescription refills and delivers personalised information regarding patients' diseases, conditions, and medications. Patients must confirm wirelessly that they complied with reminded action.
IMetrikus (Wexler, 2001)	Enables self-tests and results can be submitted via the 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 any typing errors. The application would also be capable of alerting patients in cases such as going to an emergency room or calling the doctor if readings go beyond a certain threshold.
British Engineering and Physical Sciences Research Council (Van Impe, 2001)	Remote monitoring of patient's health by receiving data gathered by a single device and then sent through a regular mobile phone.
Arbonaut and Virtual Medical World Solutions (Poropudas, 2001)	Telemedicine platform for continuous monitoring of vital parameters. Addressed to patients with a 'stable medical condition that allows a near normal life but may suddenly deteriorate and put life at risk.'
Maglaveras *et al.,* (2002)	Generic contact centre handles problems regarding remote home care.
Bludau (2003)	Bluetooth enabled sensors and a GSM/UMTS telecommunication system 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.

Although, as shown above, several technologies could be used, in order to provide a virtual permanent connection with the healthcare system, the device should belong to the patient and be independent from other communication devices that may be present in the office or at home. On the other hand, for increased reliability and decreased communication costs, when the patient is in a static location the device should be flexible and allow, as an advanced feature, a wireless link to the landline telephone network or to computers connected to the internet.

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 (Duan, 2003). These devices should be simple, robust, and follow usability guidelines to ensure ease of use and acceptance by all patients irrespective of their age, condition, and skills.

Customisation should allow for various combinations of text and voice input and output (Bludau, 2003). However, special care should be taken with innovative technical equipment.

All the above-mentioned 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 the 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 either from the central system or from the patients, this compensates for any temporary downtime in the wireless network.

5 Business case for mobile self-management of diabetics

Healthcare agencies spend $98 billion a year to care for the 16 million Americans with diabetes, according to the Centers for Disease Control (Edwards, 2002). Given this high cost associated with treating diabetes, the estimated benefits and costs of the proposed diabetes mobile self-management solution are discussed below. Statistics of diabetics' costs in the USA presented in Table 3 show that an important segment of patients with diabetes are treated out of hospitals. This would be the target market for a diabetes self-management system supported by wireless technology.

Table 3 Statistics of diabetes cases, place of treatment, and outcomes in the USA

Statistic	*Total Count*
Ambulatory care (Cherry *et al.*, 2003)	
Number of visits to office-based physicians	26.9 million (2001)
Number of hospital outpatient department visits	2.6 million (2001)
Hospital inpatient care (Hall and DeFrances, 2003)	
Number of discharges	562,000 (2001)
Average length of stay	4.9 days (2001)
Home healthcare (CDC, 2003a)	
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 (Arias *et al.*, 2003)	
Number of deaths	71,372 (2001)
Deaths per 100,000 population	25.1 (2001)
Cause of death rank	6 (2001)

Adopting a proactive attitude (both patients and healthcare system) and remotely monitoring diabetics' conditions would draw both immediate and potential savings. The two areas of savings are discussed next.

5.1 Immediate savings

The goal of keeping patients in ambulatory treatment would bring huge savings to the system, since hospitals would be dealing primarily with truly acute cases.

Reduced hospitalisation: Considering the daily cost of hospitalisation, even shortening the period of acute care for a patient would generate significant savings. 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' (Zeidenberg, 2003). People empowered by the mobile self-management solution could stay at home with reduced health risks and improved quality of care.

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 UK by Moore and Wesson (2002) has shown that 80% of community nurses' time is consumed with five types of diseases: pressure ulcers, incontinence, cancer, diabetes, and elderly care. By utilising remote monitoring, some of the home care personnel routine tasks, which do not require the nurse's physical presence, will be replaced by remote communications. The homecare system will save time and money without diminishing the patients' quality of care. Moreover, home care personnel would have more time for precious human interaction with patients.

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 USA (Landis *et al.*, 2003a). 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 (Landis *et al.*, 2003a). Savings resulted primarily because employees with improved glycemic control had lower rates of both absenteeism and restricted work activity. Hence, there is increasing interest in disease management by employers.

5.2 Potential savings

Besides direct costs, hospitalisation is undesirable for diabetics because of physical, psychological, and social reasons. Continuous monitoring of diabetics' health state would prevent unexpected deterioration of a patient's 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, the mobile and wireless solution would prevent 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 the patient, society, and the healthcare system (Coursaris, 2003; Cowling, Newman and Leigh, 1999; Silver, 2003; Yahoo! News, 2002). 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 (Lifetoolz, 2003).

If a patient can be cared for out of hospital and live a normal life while, at the same time, the healthcare system addresses his/her disease, the patient's psychological state would improve. Patient education is also an important issue. Involving the patients actively in the prescribed treatment plan, and equipping them with needed knowledge, makes them become more responsible. Thus, they learn to adjust their own care in terms of diet, medication, physical efforts, etc., in order to prevent the deterioration of their medical condition (Bludau, 2003; Lifescan, 2003).

5.3 Costs

Several researchers have shown that costs of a diabetes remote monitoring 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' (Edwards, 2002). A remote monitoring device for diabetics 'will cost about as much as a single trip to the local emergency room' (Duan, 2003). Therefore, the potential savings are high, in addition to an improved quality of life for the patient.

Research also suggests 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 hospitalisation' (Duan, 2003). 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 costs associated with work and system maintenance.

Future research will have to examine more extensively the business aspects of the self-management of diabetes based on mobile and wireless solutions of the type suggested in this paper. This research will have to identify elements, such as the cost of the device, system development, operation, and maintenance, the aggregate monetary savings brought to the healthcare system, as well as the critical mass of mobile devices that would make the service viable irrespective of the presumably high implementation costs.

6 Conclusions and future development

Disease management programmes through various components, and in particular self-management, have been shown to improve the quality of life for patients afflicted with a chronic illness. Diabetes is one such disease affecting hundreds of millions of

people around the world, regardless of age, gender, socio-economic, cultural, and educational background (CDC, 2003b). For some segments of diabetics it may be possible to treat this disease out of hospitals while living an active life. Wireless technology can be harnessed in state-of-the-art mobile applications facilitating the self-management of diabetes by reminding patients about medication and diet, blood glucose monitoring with configurable alarms and alerts, as well as allowing remote consultation and emergency intervention. Such patient-driven, technology-enabled applications can enhance the quality of care, extend it to more patients, and reduce the cost of healthcare through various direct and indirect savings. Although the mobile wireless self-management for diabetics makes sense in theory, its implementation and adoption may still face many challenges. Therefore, it is important for future research to survey patient and healthcare providers in order to assess the likelihood of endorsement of the proposed approach presented in this paper.

Some physicians strongly advocate running pilot projects in diabetes disease management, because they would not only lead to patients' improved state of health, but also to a greater acceptance of information technology in this sensitive sector (Silver, 2003). Despite the doubts still present among the healthcare sector (Frost and Sullivan, 2003), successful mobile applications in the self-management of diabetes may open the door for similar solutions in other chronic diseases (e.g., asthma or hypertension) with significant social and financial impact. Mobile applications involving self-management would make sense for manageable diseases that could allow patients to live an active and normal life, while they may be less suitable for incurable diseases that gradually result in the deterioration of the patient's health state. Basic, but fully functional, mobile commerce applications involving patients would increase the confidence in mobile and wireless technology applied in healthcare. This is expected to have a push effect for the other actors of the healthcare system, thus convincing the conservative medical system of the value of m-healthcare (Wireless Watch Japan, 2003). New dimensions of remote monitoring and care could be realised in the future if multimedia messaging services able of embedding 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 countrywide electronic healthcare systems such as, for instance, Electronic Health Record system expected to be in place in Canada by 2010 (Canada Health Infoway, 2003).

Ultimately, this is an affordable step towards the ideal system foreseen by some researchers where all segments of the healthcare system (i.e., patients, hospitals, clinics, home care, insurance, and pharmacies) would be able to echo timelessly and in a mobile context information and communication with the same goal: better serving the patients with less human and financial efforts.

Acknowledgements

The authors thank the editor and the reviewers for their constructive and thoughtful comments on an earlier version of the manuscript.

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