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A Pervasive Technology Solution for Diabetes Using Gestational Diabetes as a Model

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ABSTRACT

Diabetes is one of the leading chronic diseases affecting Australians and its prevalence continues to rise. Diabetes is therefore becoming a serious challenge for both the quality of healthcare and expenditure in the Australian healthcare system. The goal of this study is to investigate the development and application of a pervasive wireless technology solution to facilitate the effective management of diabetic patients, using the context of the care of women with gestational diabetes, a form of diabetes that affects up to 8% of pregnant women as a test case. Integral to the success of this solution is the unique software technology developed by INET to enable mobile phones to facilitate superior diabetes self-management.

Keywords

Australia, healthcare, diabetes, gestational diabetes self-management, wireless, pervasive technologies

INTRODUCTION

Diabetes mellitus [diabetes] is one of the leading chronic diseases affecting Australians and its prevalence continues to rise. The total number of diabetes patients worldwide is estimated to rise to 366 million in 2030 from 171 million in 2000 (Wild, Roglic, Green, Sicree and King, 2004). With increasingly growing prevalence which includes an estimated 275 Australians developing diabetes daily (DiabetesAustralia, 2008), Australia is expected to be a significant contributor to this projected trend. An estimated 700,000 Australians, representing approximately 3.6% of the population, were diagnosed with diabetes in 2004-05. Between 1989-90 and 2004-05 the proportion of Australians diagnosed with this disease more than doubled from 1.3% to 3.3%. Additionally, between 2000-01 and 2004-05, Australian diabetes hospitalisations increased by 35% from 1,932 to 2,608 hospitalisations per 100,000 people (AIHW, 2008). For every person diagnosed with diabetes, it is estimated that there is another who has yet to be diagnosed, which doubles the number of diabetes sufferers (DiabetesAustralia, 2008). Diabetes is, thus, one of the fastest growing chronic diseases in Australia (AIHW, 2008, Catanzariti, Faulks and Waters, 2007, Chittleborough, Grant, Phillips and Taylor, 2007).

Diabetes and its complications incur significant costs for the health system in Australia, including costs incurred by carers, government, and the entire health system (DiabCostAustralia, 2002). In 2004-05 direct healthcare expenditure on diabetes was A\$907 million, which constituted approximately 2% of the allocatable recurrent health expenditure in that year (AIHW, 2008). Further costs include societal costs that represent productivity losses for both patients and their carers (DiabCostAustralia, 2002).

Recognizing the need to have a solution that can enable the ubiquitous monitoring of diabetes patients while also continuously educating them, the goal of this paper is to investigate the development and application of DiaMonD – a diabetes monitoring device. Powered by pervasive technology software developed by INET, DiaMonD is a wireless enabled mobile phone that can facilitate superior diabetes self-management in the Australian setting. The realization of this goal can contribute by establishing a benchmark for theoretical and empirical testing. To achieve this goal, first we provide a general background on the Australian health scene and critically review existing research and then, we elaborate the proposed pervasive mobile technology solution and the anticipated barriers and facilitators in the Australian setting.

CURRENT AUSTRALIAN HEALTH SCENE

Both healthcare professionals and diabetes patients require quality information if disease conditions are to be effectively managed. There are several deficiencies in the information provided by the existing system for monitoring diabetes in Australia (Dixon and Webbie, 2006, Sprivulis, Walker, Johnston, Pan, Adler-Milstein, Middleton and Bates, 2007, Swerissen and Taylor, 2008). First, data collected in hospitals are episode-based rather than patient-based, making it difficult to determine statistics concerning individual admissions, re-admissions, and treatment patterns. Second, there is a lack of data on incidence and prevalence by diabetes type, so as to assess reliably the magnitude of the problem. Third, the accuracy of recording data in administrative data sets, such as hospital morbidity, mortality and general practice data, is uncertain. Finally, clinical management information is derived from uncoordinated and fragmented data collections that are not representative of the entire population of diabetes patients, making comparison, analysis and trend identification difficult.

These deficiencies are the result of the current health system set up. Based on fee-for-service episodic doctor-patient consultation, the current Australian healthcare system is well placed to handle short-term illnesses involving a limited range of interventions including their diagnosis and treatment (Hunt, 2007). However, this system is comprised of a mixture of fragmented private and public healthcare subsystems that provide both healthcare funding and delivery. Largely uncoordinated, these subsystems are deemed to be unsuitable for the treatment of long-term chronic diseases, including diabetes (Dixon and Webbie, 2006, Sprivulis et al., 2007). In particular, the chronic and multisystem nature of diabetes and its complications requires teams of various health professionals and long-term support to help sufferers make effective healthy lifestyle changes and constantly maintain them (Hunt, 2007).

CURRENT DIABETES SELF-MANAGEMENT RESEARCH

As there is no cure for diabetes, non-medical approaches are used jointly with medical approaches, so that patients with the disease can have a life which is as normal as possible. Such non-medical approaches require effective and ongoing lifestyle management, together with meticulous attention and monitoring by both patients and healthcare professionals (Britt, Miller, Charles, Pan, Valenti, Henderson, Bayram, O'Halloran and Knox, 2007). Particularly, to be successful, patients need to be both informed and active in their treatment regimen (AIHW, 2008, AIHW, 2007). These aims can be achieved by effective self-management, which is a non-medical approach and which constitutes the focus of this paper.

Self-management is important as it empowers diabetes patients while acknowledging their central role and responsibility for managing their healthcare (ICIC, 2008). Active participation of diabetes patients in self-management is a key strategy for managing their condition and reaching improved treatment outcomes (Colagiuri, Colagiuri and Ward, 1998, Poulton, 1999, Rasmussen, Wellard and Nankervis, 2001, Wellard, Rennie and King, 2008). However, self-management is constantly time-consuming and requires significant self-discipline (Russell, Churl Suh and Safford, 2005) and support strategies including assessment, goal-setting, action-planning, problem-solving and follow-up (ICIC, 2008). Moreover, because effective self-management may require patient interaction with various healthcare professionals, including diabetes physicians, general practitioners, diabetes educators, dieticians, and community nurses (Knuiman, Welborn and Bartholomew, 1996), difficulties can arise when diabetes patients encounter problems ranging from making appointments to needing to travel to many locations (Van Eyk and Baum, 2002, Wellard et al., 2008, Zigbor and Songer, 2001). Given both the importance and complexity of applying self-management effectively for both prevention and early detection of diabetes, there are increasing calls for further research to facilitate self-management (Wellard et al., 2008).

Solutions for supporting self-management (Chau and Turner, 2006, Rudi and Celler, 2006) have not always been effective, due to the reality that “patients did not learn how to do it [apply the solutions] or they did not understand the rules which were explained to them, or they were not sure enough of their knowledge, uncertainty entailing indecision” (Reach, Zerrouki, Leclercq and d'Ivernois, 2005). On the other hand, computer-assisted telemedicine can help people with diabetes improve both their self-management (Balas, Krishna, Kretschmer, Cheek, Lobach and Boren, 2004) and their relationship with healthcare professionals (Bodenheimer, Lorig, Holman and Grumbach, 2002, Downer, Meara, Da Costa and Sethuraman, 2006).

THE CASE OF GESTATIONAL DIABETES

Gestational diabetes (GDM) is a common form of diabetes that presents in pregnancy, sometimes with symptoms but often diagnosed in otherwise normal women on a routine screening test. Some women, particularly those in whom the diagnosis of GDM is made early in pregnancy, may have pre-existing undiagnosed diabetes. In Australia and New Zealand, universal screening for GDM is recommended by the Australasian Diabetes in Pregnancy Society (ADIPS) (Hoffman, Nola, Wilson, Oats and Simmons, 1998), although the uptake of the recommendation is rather variable (Rumbold and Crowther, 2001). It is estimated that in Australia, 3-6% of pregnant women will develop GDM at around 24-28 weeks gestation, with a smaller number earlier and later in pregnancy. An Australian study of 210 pregnant women found that screening for GDM had an adverse impact on women's perceptions of their own health (Rumbold and Crowther, 2002). GDM is more common in older women, in those with a family history of diabetes, in those who are overweight and in those of non-Caucasian heritage. Maternal complications of GDM include polyhydramnios and premature labour, and pre-eclampsia (Hoffman et al., 1998). It recurs in subsequent pregnancy in 30-80% of women, the incidence varying with ethnicity, being lower in Caucasian women (Kim, Berger and Chamany, 2007).

Treatment of women with GDM aims to control maternal, and therefore fetal, hyperglycaemia and the associated tendency to fetal hyperinsulinaemia, which is at the root of the fetal complications (Metzger et al., 2008). After many years of uncertainty as to the value of such treatment in GDM, two trials have now shown benefit for both mother and offspring for antenatal initiation of lifestyle modification and glucose monitoring, coupled with insulin therapy as necessary (Crowther, Hiller, Moss, McPhee, Jeffries and Robinson, 2005, Landon et al., 2009). Antenatal treatment of screen detected mild GDM was also associated with improved health status for women during the antenatal period and at 3 months after birth, with less postnatal depression (Crowther et al., 2005).

Critical to the GDM and to successful pregnancy outcome is careful and systematic monitoring of maternal glycaemia and appropriate adjustment of lifestyle, dietary and pharmacological therapy in the light of the results. Therefore, in this paper, we investigate the development and application of DiaMonD as a pervasive mobile technology solution to facilitate superior diabetes self-management in the case of women with GDM.

Component	Description
Organisation of Health System	Leadership in chronic disease management (CDM) Goals for CDM Improvement strategy for CDM Incentives and regulations for CDM Benefits
Self-management support	Assessment and documentation of needs and activities Addressing concerns of patients Effective behaviour change interventions
Decision Support	Evidence-based guidelines Involvement of specialists in improving primary care Providing education for CDM Informing patients about guidelines
Delivery System design	Practice team functioning Practice team leadership Appointment system Follow-up Planned visits for CDM Continuity of Care
Clinical Information Systems	Registry Reminders to providers Feedback Information about relevant subgroups of patients needing services Patient treatment plans
Community	Linkages for patients to resources Partnerships with community organizations Policy and plan development

Table 1. Components of Chronic Care Model (Rachlis, 2006)

THE DEVELOPMENT OF A PERVASIVE MOBILE TECHNOLOGY SOLUTION

We propose DiaMonD – diabetes monitoring device – as a solution which incorporates software that facilitates the ubiquitous monitoring of an individual’s diabetes, thereby, contributing to diabetes self-management. The solution is grounded in trying to support key components of a chronic disease care model (Table 1). INET International Inc.’s research (Goldberg, 2002a, Goldberg, 2002d, Goldberg, 2002b, Goldberg, 2002e, Goldberg, 2002c, Wickramasinghe and Goldberg, 2004, Wickramasinghe and Goldberg, 2003) starts with a 30-day e-business acceleration project in collaboration with many key players in hospitals, such as clinicians, medical units, administration, and I.T. departments. Together, they follow a rigorous procedure that refocuses the traditional 1-5-year SDLC into concurrent 30-day projects to accelerate healthcare delivery improvements. At completion, an e-business acceleration project delivers a scope document to develop a handheld technology application (HTA) proof-of-concept specific to the unique needs of a particular environment. The proof-of-concept is a virtual lab case scenario which operates within a mobile Internet (wireless) environment by working with hospitals and technology vendors. The final step is the collection of additional data with clinical HTA trials consisting of two-week hospital evaluations.

The INET web-based model (figure 1) provides the necessary components to enable the delivery framework to be positioned in the best possible manner so it can indeed facilitate enacting the key components of the chronic disease model successfully (table 1). The model is positioned to suit the complex nature of healthcare environments by iteratively, systematically, and rigorously incorporating lessons learnt data to healthcare processes for ensuring superior healthcare delivery. This manner not only maximizes the value of past data and organisational learning, but it also makes processes amendable as complex needs and requirements evolve.

It is important to note that in the INET web-based model the three key areas of risk, namely, people, processes and technology, are minimized through the use of pervasive technology, which we believe is a unique benefit of the INET solution. Specifically, since the proposed solution is an application that is compatible with any mobile phone or wireless device (e.g. a PDA), data transfers occur between patients and providers on a well-vetted model. Therefore, the learning curve for patients may be minimal as they are likely to be in possession of mobile devices.

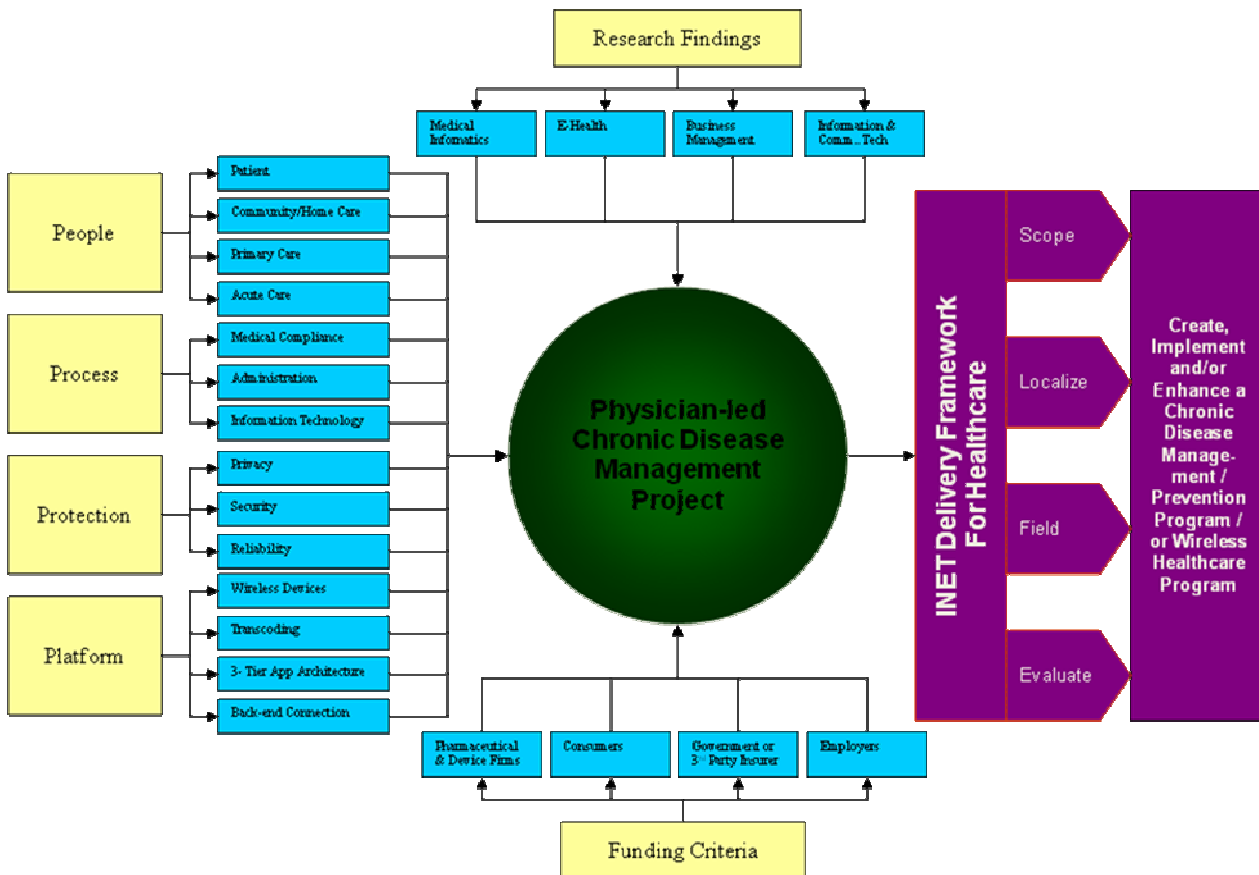


Figure 1. INET web-based model

What makes this model unique and most beneficial is its focus on enabling and supporting all areas necessary for the actualization of ICT initiatives in healthcare. By design, the model identifies the inputs necessary to bring an innovative chronic disease management solution to market. These solutions are developed and implemented through a physician-led mobile e-health project. This project is the heart of the model that bridges the needs and requirements of many different players into a final (output) deliverable, a “Wireless Healthcare Program”. To accomplish this, the model is continually updated to identify, select and prioritize the ICT project inputs that will:

- Accelerate healthcare system enhancements and achieve rapid healthcare benefits. The model identifies key healthcare system inputs with the four Ps, namely, 1) **P**eople that deliver healthcare, 2) **P**rocess to define the current healthcare delivery tasks, 3) **P**latform used in the healthcare technology infrastructure, and 4) **P**rotection of patient data.
- Close the timing gaps between information research studies and their application in healthcare operational settings.
- Shorten the time cycle to fund an ICT project and receive an adequate return on the investment.

These 4 Ps were chosen after discussions with various healthcare professionals as to the areas they believed were critical inputs for any model. These categories are mutually exclusive and collectively exhaustive based on the views of experts consulted. In applying the INET-based solution to any particular context of diabetes sufferers it is necessary to consider the scope or extent of the diabetes problems in this context, the specific contextual features such as demographics as well as current processes in place to treat patients so that the application will be tailored to this population hence “localize” is an important aspect in the delivery frame work. In addition, it is important to understand the make-up of the care team or field and finally results need to be evaluated.

Thus, the delivery framework helps to make the solution applicable to any context of diabetes patients which is an essential consideration given that diabetes cuts across all areas of the community. Together the components of the model will help in actualizing physician-led solution for the management of chronic diseases in general and of diabetes in particular. To successfully implement the INET web-based model described above, it was necessary to have an appropriate methodology. Based on this need, the adaptive mapping to realization methodology (AMR) was developed (figure 2). The idea of the methodology was to apply a systematic rigorous set of predetermined protocols to each business case and then to map the post-prior results back to the model. In this way, it was possible to compare and contrast both a priori and post priori findings. From such a comparison, first a diagnosis of the current state was made, then prescriptions were derived for the next business case. Hence, each pilot study incorporated the lessons learnt from the previous one and the model was adapted in real time.

By applying the tools and techniques of today’s knowledge economy as presented in the intelligence continuum (IC), it is possible to make the AMR methodology into a very powerful knowledge-based systems development model. The IC was developed by Wickramasinghe and Schaffer (2006) to enable the application of tools and technologies of the knowledge economy to be applied to healthcare processes in a systematic and rigorous fashion, thereby ensuring superior healthcare delivery. The collection of key tools, techniques and processes that make up the IC include, but are not limited to, data mining, business intelligence/analytics and knowledge management (Wickramasinghe and Schaffer, 2006).

Taken together, they represent a very powerful system for refining the raw data stored in data marts and/or data warehouses, thereby maximizing the value and utility of these data assets for any organization. To maximize the value of the data generated through specific healthcare processes and then to use this to improve processes, IC techniques and tools must be applied in a systematic manner. Once applied, the results become part of the data set that are subsequently reintroduced into the system and combined with other inputs of people, processes, and technology to develop an improvement continuum. Thus, the IC includes the generation of data, the analysis of these data to provide a “diagnosis”, and their reintroduction into the cycle as a “prescriptive” solution. In this way, the IC is well suited to the dynamic and complex nature of healthcare environments and ensures that the future state is always built upon the extant knowledge-base of the preceding state. Through the incorporation of the IC with the AMR methodology we then have a knowledge-based systems development model that can be applied to any setting, not necessarily to chronic disease management. The power of this model is that it brings best practices and the best available germane knowledge to each iteration and is both flexible and robust.

Given the uniqueness of this approach it was necessary to develop this model from the beginning rather than look at other existing models. This was done by trying to understand key criteria from various stakeholders such as patients, healthcare professionals and hospital personnel and sort this information into a coherent whole. This was an iterative process which involved many and multiple discussions with the various stakeholders until all parties were agreed the model captured the essential elements as discussed in details in Goldberg (2002a-e)

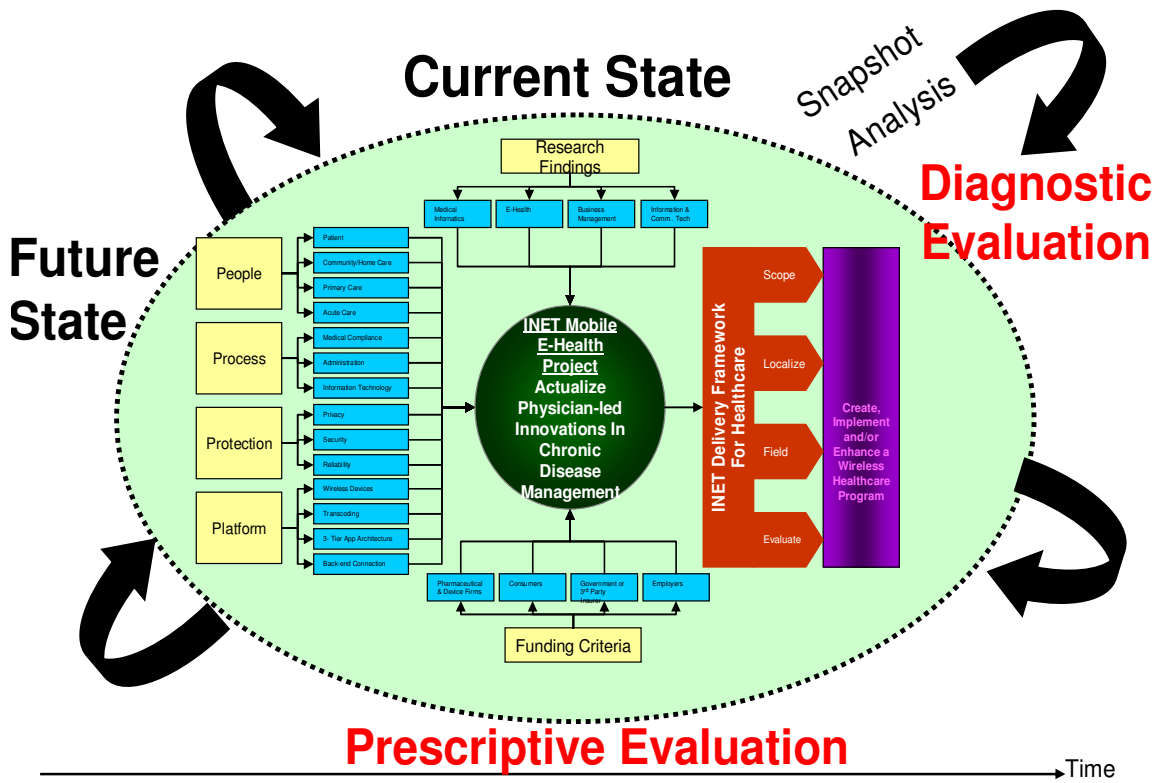


Figure 2. AMR Methodology

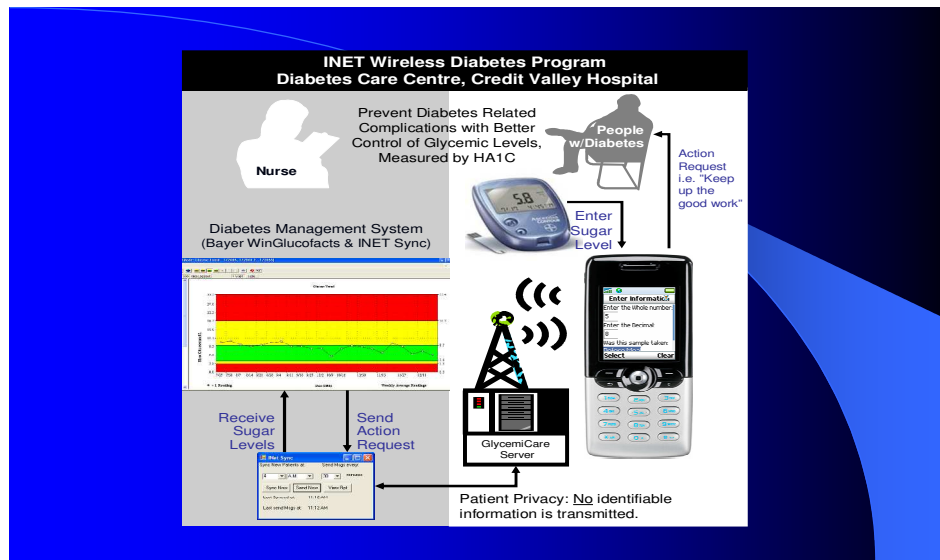


Figure 3. ICT Support for Diabetes

To date directional data (Wickramasinghe and Goldberg, 2007) has already shown the benefits of this solution in various pilot studies in Canada. We believe that DiaMonD is a most beneficial solution given the huge and growing impact of diabetes. In particular, it is very cost effective for both patients and healthcare providers. We believe that as more pilot studies are conducted in different settings this will add data that will show the full and far reaching benefits of the proposed solution. What is certain is that current methods for treating patients with diabetes are unwieldy, generating significant costs, not especially patient-centric and doing little to stem the development of secondary complications thus a better solution is required. At this stage, the INET's solution looks to be appropriate.

Thus, DiaMonD represents a pervasive ICT enabled solution, which, while not exorbitantly expensive, can facilitate the superior monitoring of diabetes (figure 3). The proposed solution enables patient empowerment by way of enhancing self-management. This is a desirable objective because it allows patients to become more like partners with their clinicians in the management of their own healthcare (Opie, 1998, Radin, 2006) by enhancing the traditional clinical-patient interactions (Mirza, Norris and Stockdale, 2008). However, because most work has focused on specific applications and proof-of-concept studies, this paper would be incomplete without considering the critical success factors, including facilitators and barriers, that are expected to affect the ubiquitous adoption of the proposed solution in the Australian setting (Gururajan and Murugesan, 2005, Mirza et al., 2008).

CONCLUSIONS

Given the general global consensus that effective and efficient healthcare delivery will only occur through the judicious application of ICTs (FS, 2004, Kulkarni and Nathanson, 2005, Lacroix, 1999, Porter and Tiesberg, 2006, Wickramasinghe, 2007), it is inevitable that, as we move into the second decade of the 21st century, the prevalence of ICTs to facilitate the delivery of value-driven healthcare will increase. In such a climate, DiaMonD will be even more appropriate, not only because it utilises ICTs to provide superior healthcare delivery in the case of diabetic patients, but also because it is both simple to implement and use, and also cost effective both at the micro and macro levels. These levels include individual patients, clinicians and organisations, including public and private healthcare providers.

We set out to present a case for the need to embrace a pervasive technology solution for the superior monitoring of diabetes self-management for patients with diabetes in Australia, using gestational diabetes as an initial model. We would contend that, as developed by INET, DiaMonD is a suitable wireless solution for many reasons, including that it is equally successful in controlling both type I and type II diabetes, is as effective irrespective of patient's age, socio economic standing or location and has minimal risks and a very slight learning curve (if at all). Moreover, we strongly believe that, if DiaMonD and its underlying model were to be incorporated into the Australian context, the growing segment of the population suffering from diabetes would have a convenient, cost effective and superior means of monitoring, and thereby controlling, their diabetes, while in turn enjoying a better quality of life.

DiaMonD facilitates governments, associations, pharmaceutical firms, researchers, healthcare professionals and other healthcare stakeholders that are looking for improved and measurable outcomes among patients suffering from diabetes. Specific benefits range from decreasing diabetes-related complications to reducing the economic burden on the health system. We realise that further research is required to test DiaMonD in the Australian healthcare setting including testing of aspects, such as perceived ease of use, perceived usefulness, etc. We conclude by warning that, if a pervasive technology solution is not sought for the monitoring and support of diabetes self-management, then this chronic disease, which is already at pandemic level, will continue to be a very costly burden for both the healthcare sector and the community at large.

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