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A Transaction Cost Assessment of a Pervasive Technology Solution for Gestational Diabetes

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ABSTRACT

Diabetes is one of the leading chronic diseases affecting Australians and its prevalence continues to rise. It is 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 diabetes in the context of women with gestational diabetes. Gestational diabetes is a form of diabetes that affects up to 8% of pregnant women. A transactions cost assessment of this solution is also provided. Integral to the success of this solution is the pervasive technology solution which serves to support and facilitate superior diabetes self-management.

Keywords: Chronic Diseases, Gestational Diabetes, Healthcare, Pervasive Wireless Technology, Self-Management

INTRODUCTION

Diabetes mellitus 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 380 million in 2025 from 246 million in 2007 (Wild et al., 2004). With increasingly growing prevalence which includes an estimated 275 Australians developing diabetes daily (Diabe-

tesAustralia, 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 hospitalizations increased by 35% from 1,932 to 2,608 hospitalizations per 100,000 people (AIHW, 2007, 2008). For every person diag-

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nosed 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, & Waters, 2007; Chittleborough et al., 2007). Diabetes and its complications incur significant costs for the health system in Australia, including costs incurred by care providers, 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 recurrent health expenditure that is to be allocated in that year (AIHW, 2007, 2008). Further costs include societal costs that represent productivity losses for both patients and their care providers (DiabCostAustralia, 2002).

Gestational diabetes mellitus (GDM) is a common form of diabetes that presents in pregnancy, sometimes with symptoms but often diagnosed in otherwise normal women on routine screening tests. 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 et al., 1998), although the uptake of this recommendation is rather variable (Rumbold & 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 & Crowther, 2001, 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 (Carolan, Steele, & Margetts, 2010). Maternal complications of GDM can be serious and include polyhydramnios and premature labor, maternal hypertension, low birth weights and stillbirth (Fan et al., 2006; 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, & Chamany, 2007).

Treatment of women with GDM aims to control maternal, and therefore fetal, hyperglycaemia and the associated tendency of 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 et al., 2005; Landon et al., 2009). Antenatal treatment of 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). Specifically, there is agreement in the literature that specific self-management activities including glucose monitoring, dietary restrictions, and exercise regimes can result in good outcomes for mothers and babies suggesting that self-management behaviors can be critical (Crowther et al., 2005; Fan et al., 2006).

Recognizing the need to have a solution that can enable the ubiquitous monitoring of GDM patients while also facilitating self-management and continuously educating them, the goal of this paper is to investigate the development and application of DiaMonD – a diabetes monitoring device. To the best of our knowledge, there exists no other software solution that focuses on individuals suffering from gestational diabetes; hence the DiaMonD solution serves as an exemplar case study in this discussion. Specifically, we set out to answer the research question “how can DiaMonD benefit and facilitate superior care for GDM patients?” Powered by pervasive technology software developed by INET, DiaMonD is a wireless-enabled mobile phone that can facilitate superior diabetes self-management for GDM patients. The realization of this goal can contribute by establishing a benchmark for theoretical and empirical testing. We examine DiaMonD in the context of GDM. Critical to the GDM and to

successful pregnancy outcomes is careful and systematic monitoring of maternal glycaemia and appropriate adjustment of lifestyle, dietary and pharmacological therapy in the light of the results. The end results of GDM are similar to other types of diabetes (e.g., Types 1 and 2). However, unlike other types of diabetes, GDM is generally transient which can have implications on awareness of impacts and self-management attitudes (Carolan, Steele, & Margetts, 2010; Crowther et al., 2005; Fan et al., 2006).

To achieve our 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 assess it using a preliminary transaction cost economics framework. We believe that this paper is, therefore, relevant, timely, and important to all players in the complex web of healthcare including care providers, healthcare organizations, insurers/payers, regulatory government agencies, patients, their families, and the community at large.

CURRENT AUSTRALIAN HEALTH SCENE

Both healthcare professionals and diabetic 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 & Webbie, 2006; Sprivulis et al., 2007; Swerissen & 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 difficult to ascertain. Finally, clinical management information is derived from uncoordinated and fragmented data collections that are not representative of the entire population of diabetic patients, making

comparisons, analysis and trend identification challenging.

These deficiencies are the result of the current health system setup. 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 more generally and GDM in particular (Dixon & Webbie, 2006; Sprivulis et al., 2007). In fact, the chronic and multisystem nature of diabetes and its complications require 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. Non-medical approaches require effective and ongoing lifestyle management, together with meticulous attention and monitoring by both patients and healthcare professionals (Britt et al., 2007). Particularly, to be successful, patients need to be both informed and active in their treatment regimen (AIHW, 2007, 2008). 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 diabetic patients while acknowledging their central role and responsibility for managing their healthcare (ICIC, 2008). Active participation of diabetic patients in self-management is a key strategy for managing their condition

and reaching improved treatment outcomes (Colagiuri, Colagiuri, & Ward, 1998; Poulton, 1999; Rasmussen, Wellard, & Nankervis, 2001; Wellard, Rennie, & King, 2008). However, self-management is constantly time-consuming and requires significant self-discipline (Russell, Churl Suh, & 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, & Bartholomew, 1996), difficulties can arise when diabetic patients encounter problems ranging from making appointments to needing to travel to many locations (Van Eyk & Baum, 2002; Wellard, Rennie, & King, 2008; Zigbor & 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, Rennie, & King, 2008).

Although current research has provided solutions for supporting self-management (Chau & Turner, 2006; Rudi & Celler, 2006) these 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 are not sure enough of their knowledge, uncertainty entailing indecision” (Reach et al., 2005). Additionally, a number of recent attempts at implementing diabetes self-management monitoring systems found these systems to be either impractical or costly. For example, a system implemented in France uses a combination of personal digital assistants (PDAs) and mobile phones, but downloads glucose readings data weekly or bi-weekly, potentially resulting in feedback delays for patients and, thus, questionable effectiveness and service quality (Farmer et al., 2005). A telephone support system was trialed in the UK with nurse facilitators. While this system

was shown to improve glucose readings over-time, it did not use systematic transmission of glucose results, again, potentially impacting adversely on effectiveness while also being costly to run and maintain (Young et al., 2005). Nevertheless, research shows that computer-assisted telemedicine generally can help people with diabetes improve both self-management (Balas et al., 2004) and their relationship with healthcare professionals (Bodenheimer et al., 2002; Downer et al., 2006). Here, therefore, we investigate the application of a pervasive mobile technology solution to facilitate superior self-management of GDM.

A TRANSACTION COST ECONOMICS ASSESSMENT FRAMEWORK

Transaction cost economics (TCE) theory represents a natural and logical theoretical setting for guiding the evaluation of actor interactions in a diabetes monitoring healthcare setting (Hesterly, Liebeskind, & Zenger, 1990; Hesterly & Zenger, 1993; Jones, Hesterly, & Borgatti, 1997; Troshani & Rao, 2007a; Williamson, 1991). That is, TCE focuses on economic exchange relations amongst organizational actors, including diabetic patients and healthcare providers that are typically involved in interactions. Using the TCE extensions proposed by Jones, Hesterly, and Borgatti (1997) as a basis, the interactions of these actors comprised economic exchanges, the efficiency of which is jointly determined by four conditions, namely, (1) demand uncertainty, (2) task complexity, (3) asset specificity, and (4) frequency. We explain these conditions in turn.

Demand uncertainty is defined as the inability of an actor to predict future events concerning the success or failure of new product offerings, such as a diabetes monitoring solution (Milliken, 1987; Troshani & Rao, 2007a). It can be caused by many sources including rapid changes in knowledge and technology or even by the actors themselves. Understanding potential sources of demand uncertainty is

important because it helps control it and reduces the impact of associated risks.

Task complexity refers to the number of different specialized behavioral inputs that are required to fully develop and distribute a product or service (Jones, Hesterly, & Borgatti, 1997; Troshani & Rao, 2007a). Task complexity creates behavioral interdependencies while increasing the need for coordinating actors involved in related processes (Pfeffer & Salancik, 1978; Troshani & Rao, 2007a).

Asset-specific exchanges can be based on both unique human (e.g., unique processes and knowledge developed by various actors) and non-human assets (e.g., unique equipment) which actors can use to enable economic exchanges. Asset-specific exchanges can therefore create dependencies, which, in turn, would require enhanced cooperation, coordination, and proximity for the effective transfer of assets or their deliverables amongst actors (Jones, Hesterly, & Borgatti, 1997; Troshani & Rao, 2007a; Williamson, 1991).

Frequency concerns how often actors are involved in exchanges with each another (Jones, Hesterly, & Borgatti, 1997; Williamson, 1985). Jones, Hesterly, and Borgatti (1997) argue that “frequency allows human asset specificity to develop from learning-by-doing and to “deepen” through continued interaction; this creates exchanges where the “identity” of the other [actors] matters and enhances the transfer of tacit knowledge...” (p. 922) while also maximizing the cost efficiencies of existing interaction structures (Troshani & Rao, 2007a; Williamson, 1985).

DEVELOPMENT OF A PERVASIVE MOBILE TECHNOLOGY SOLUTION

In our case exemplar, we examine DiaMonD, a diabetes monitoring device, as a solution which incorporates software that facilitate the ubiquitous monitoring of an individual’s GSM, 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, 2002b, 2002c, 2002d, 2002e, 2009; Wickramasinghe & Goldberg, 2003, 2004) starts with a 30-day e-business acceleration project in collaboration with many key players in hospitals, such as clinicians, medical units, administration, and IT departments. Together, they follow a rigorous procedure that re-focuses the traditional 1-5-year system development lifecycle (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 not only maximizes the value of past data and organizational 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

Table 1. Components of a chronic care model (Rachlis, 2006)

Component	Description
Organization 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 behavior 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

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. We note that while the INET model was developed to provide self-management support for any/all diabetes sufferers, the focus of this paper is primarily on patients suffering from GDM, i.e., a specific subset of all diabetes sufferers.

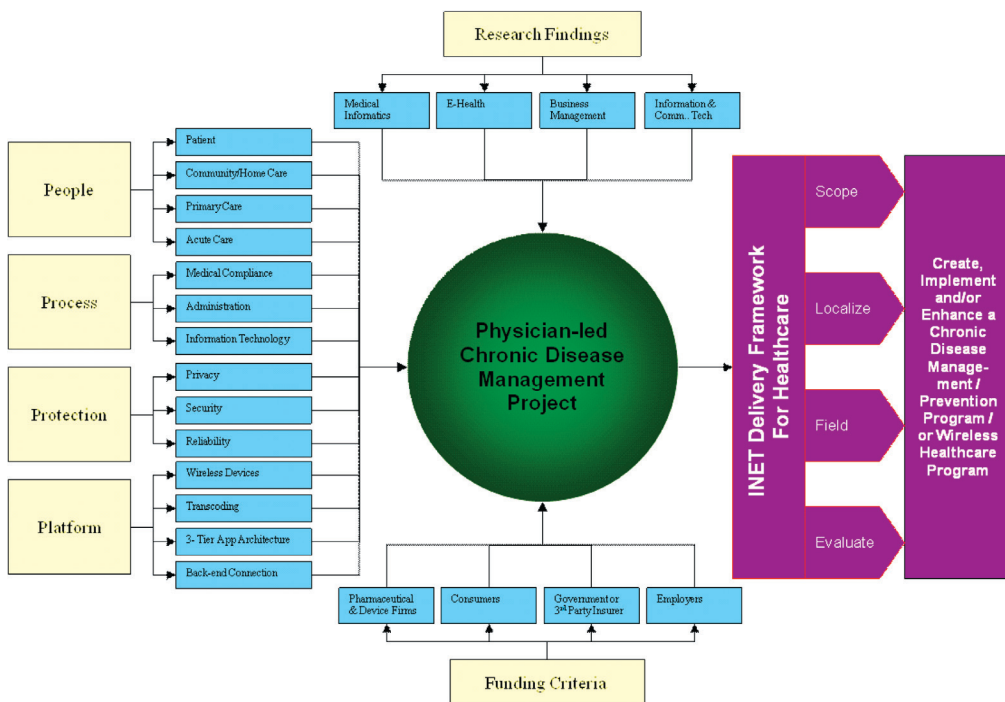
What makes this model unique and most beneficial is its focus on enabling and supporting all areas necessary for the actualization of ICT initiatives in healthcare. By design, the model identifies the inputs necessary to bring an innovative chronic disease management solution to market. These solutions 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) People that deliver healthcare,
 - 2) Process to define the current healthcare delivery tasks,
 - 3) Platform used in the healthcare technology infrastructure,
 - 4) Protection of patient data.
- Close the timing gaps between information research studies and their application in healthcare operational settings.

Figure 1. INET Web-based model



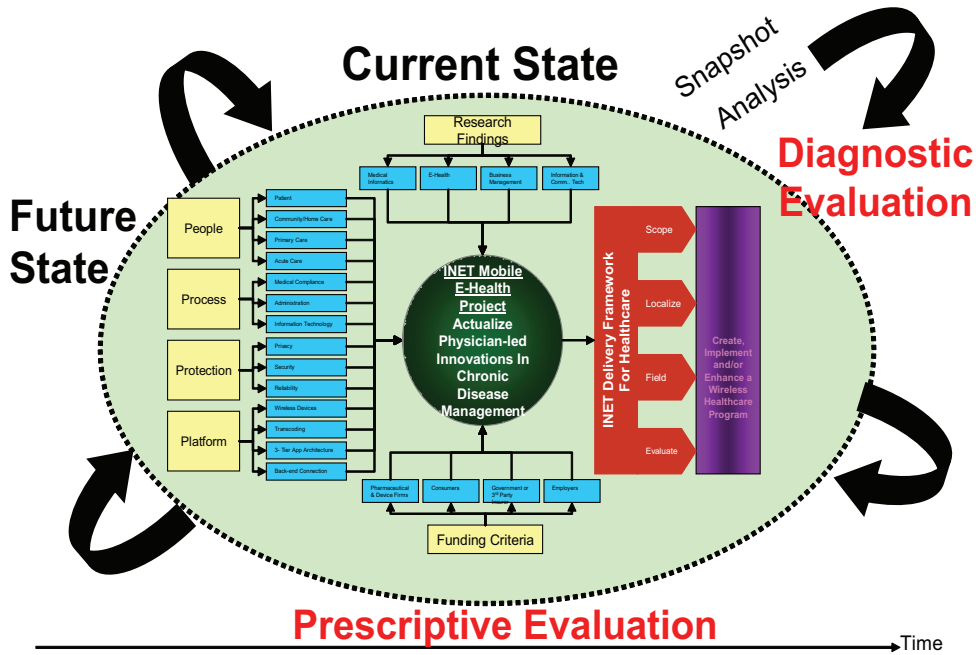
- Shorten the time cycle to fund an ICT project and receive an adequate return on the investment.

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 and legacy systems in place to treat patients so that the application will be tailored to this population - hence “localize” it which constitutes an important aspect in the delivery framework. In addition, it is important to understand the make-up of the care team or field and finally the results that need to be evaluated. Thus,

the delivery framework aids in making the solution applicable to any context of diabetic patients which is an essential consideration given that diabetes cuts across many 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

Figure 2. AMR methodology



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 an 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 & Schaffer, 2006).

Taken together, the IC represents 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 iterates best practices and

best available germane knowledge continually and is both flexible and robust.

Given the uniqueness of this approach it was necessary to develop this model separately rather than linking it to other existing models. This was done by first, trying to understand key criteria from various stakeholders such as patients, healthcare professionals and hospital personnel, and then, sorting the information into a coherent whole. This was an iterative process which involved multiple discussions with the various stakeholders until all parties achieve consensus that the model captured the essential elements as discussed in Goldberg (2002a, 2002b, 2002c, 2002d, 2002e).

To date directional data from Wickramasinghe and Goldberg (2007) have shown the potential benefits of this solution in various pilot studies in Canada. The research methodology adopted in these studies applied mixed method including standard qualitative and quantitative techniques such as survey, interview and ethnography focusing on a single exemplar case study. At all times a high level of research rigor was ensued by subscribing to recognized and standard practices as set out by Yin (1994), Boyatzis (1998), and Kavale (1996). We believe that DiaMonD is a beneficial solution given the huge and growing impact of diabetes generally and GDM in particular. 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, suggesting that a better solution is needed. At this stage, the INET's solution looks to be appropriate as it offers a real-time user-centric solution. It offers an innovative approach to transmit blood glucose readings for GDM patients while providing support and instant feedback to patients and clinicians on both mobile devices and web-browsers, significantly enhancing accessibility and patient care.

Additionally, the solution has the potential to establish critical self-management behaviors for GDM patients or, where they already exist, enhance them. It also addresses issues of existing solutions which either do not systematically capture glucose readings data or when they do, do not provide the data to clinicians in a timely manner (Farmer et al., 2005; Young et al., 2005).

Even so, DiaMonD represents a pervasive ICT enabled solution, which, while not exorbitantly expensive, can facilitate the superior monitoring of GDM (Figure 3). DiaMonD also 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, & Stockdale, 2008; Wickramasinghe, Troshani, & Goldberg, 2009, 2010).

A Preliminary Assessment of the Solution

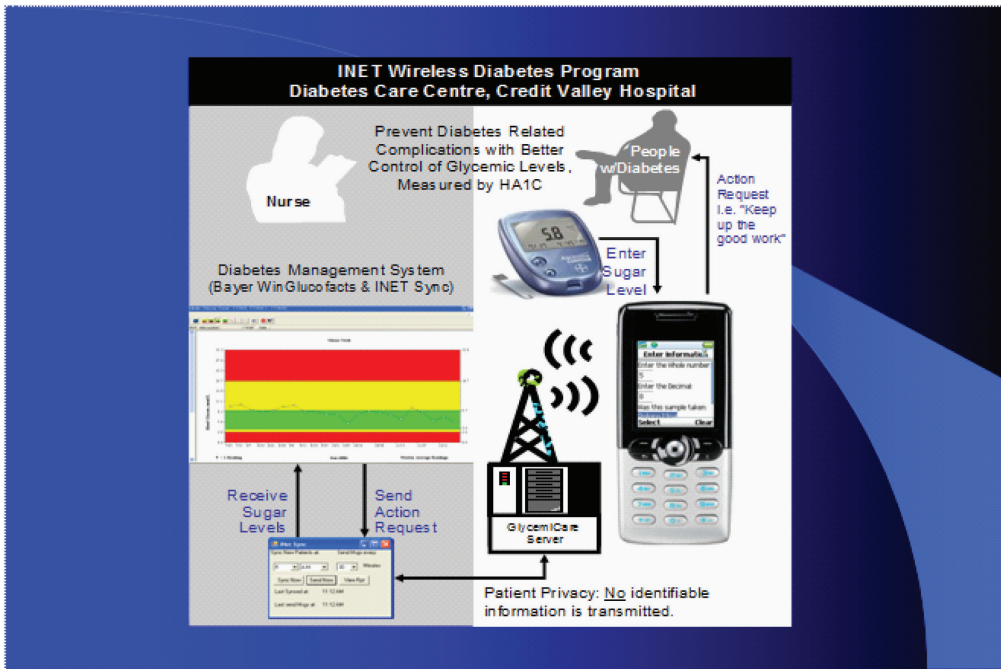
Demand Uncertainty

Given the growing incidences of diabetes and GDM sufferers and the relative ineffectiveness of existing non-medical approaches (Reach et al., 2005), it is anticipated that upon being made available there will be demand for the proposed solution, i.e., DiaMonD. Additionally, costs incurred by diabetes patients to operate the solution, that is, to systematically send glucose readings to their diabetes healthcare professionals (Figure 3), are likely to be negligible since data transfer charges have recently become inexpensive. It is, therefore, expected that uncertainty is not likely to adversely affect demand for a solution such as DiaMonD for self-management for diabetes patients generally, and GDM patients, in particular.

Task Complexity

We argue that the proposed solution is easy to use and useful for both diabetic patients and healthcare professionals. As shown in Figure

Figure 3. ICT Support for diabetes



3, DiaMonD requires diabetes sufferers to input their glucose readings systematically via a simple user interface before sending them for processing. In fact, the solution is very similar to Short Message Service (SMS) applications which are renowned for their popularity (Mackay & Weidlich, 2007; O'Doherty et al., 2010; Oh et al., 2008). It is, therefore, anticipated that diabetes sufferers will find the solution easy to use and useful as also supported in preliminary studies and assessments in previous trials both in the US and Canada (Wickramasinghe & Goldberg, 2004, 2007; Wickramasinghe, Goldberg, & Bali, 2007, 2008). Additionally, healthcare professionals that have used the proposed solution have indicated that the functionality that concerns them (Figure 3) is also easy to use and useful (Wickramasinghe & Goldberg, 2004, 2007; Wickramasinghe, Goldberg, & Bali, 2007, 2008). That is, the solution enables healthcare professionals to both monitor diabetes trends and interact with patients relatively easily, inexpensively, and pervasively on both

mobile device and browser interfaces. Therefore, we speculate that DiaMonD complexity is not likely to present issues to users including diabetes sufferers and clinicians.

Asset Specificity

We anticipate that asset specificity will not constitute an obstacle for both diabetic patients and healthcare professionals. From the patients' viewpoint, operating the proposed solution entails a mobile handset and a data plan. Current evidence shows that in many countries worldwide, including Australia, mobile penetration rates exceed 100% (Netsize, 2009; Rao & Troshani, 2006). Evidence also shows increasing trends of usage of mobile data services suggesting that there is growing numbers of mobile phone users that are subscribing to mobile data plans (Informa, 2005a, 2005b, 2006; Netsize, 2009; Rao & Troshani, 2006). Therefore, DiaMonD in its capacity as a mobile diabetes self-management solution can be run on assets, i.e., mobile handset, which diabetic

patients are likely to possess. Similar arguments can be made for healthcare professionals and their organizations. Additionally, healthcare professionals may also access DiaMonD summaries (Figure 3) using web browser interfaces which only require computers connected to the Internet and are not expected to require specific expensive assets. Thus, it is anticipated that aside from software upgrades in existing servers and corresponding license fees, upgrades to new assets including computer hardware, are most likely unnecessary.

Frequency

We anticipate that interaction frequency between diabetic patients and healthcare providers using the proposed mobile solution will be high, though dictated by particular treatment regimen that healthcare professionals assigned to their patients. For example, some patients may be required to send their glucose readings to their healthcare professional six times daily, i.e., three times daily before and after each meal, while other patients may be required to fulfill different patterns. We infer that interaction frequency is only a means of maximizing cost efficiencies, but also as a way of strengthening and complementing long term patient-healthcare professional relationships thereby improving the overall quality of healthcare services offered.

DISCUSSION

Based on our initial exploratory evaluation, the DiaMonD solution does appear to provide key benefits to GDM patients. Specifically, it would appear that the solution facilitates self-management and cost effective, convenient care. Naturally, specific costs depend largely on the particular phone provider and phone plan. However, evidence shows that most individuals today who have mobile phones also have mobile phone plans. Given the small size of the data that is transferred in the solution strategy outlined above, in most cases this is well within the allowable amount of most phone plans, and hence, it is logical to assume that for most indi-

viduals they would in fact pay little to no extra charges for their glucose data transfer. Further, costs to healthcare providers would depend on various specific and respective arrangements these providers have with their existing ICT infrastructure but in general the DiaMonD solution provides them with an opportunity for significant cost savings and streamlining of patient data and workflow. This, in turn, is likely to provide them with better processes and subsequent savings with regard to non-billable hours. Finally, for insurers better management of GDM patients translates into potentially fewer healthcare problems, and hence, also fewer claims, thereby adding to cost savings.

Limitations

This paper serves to provide an exploratory investigation using an exemplar case study to identify the potential benefits of a pervasive technology solution for gestational diabetic patients. To the best of our knowledge no other software solution currently exists that specifically focuses on the management of GDM patients. As noted by Yin (1994), exploratory exemplar case studies are essential when there is a paucity of studies in a particular area so that it is possible to begin to build theory and awareness. We have attempted to accomplish this and reported the proposed model and the manner in which DiaMonD works in the preceding section. However, like all exploratory research, it has certain limitations including the fact that the major focus and assessment was based on the DiaMonD solution. We wish to point out that presenting an objective assessment of this solution should not be seen as either endorsing or not endorsing a specific solution; rather, we present the case in order to provide a preliminary transactional cost perspective. Costs in healthcare are a very critical issue and without careful assessment of actual data it is not possible to understand, let alone address or provide recommendations regarding these significant costs issues and implications. Moreover, the findings pertaining to better management of GDM patients cannot just be translated to

all patients suffering with diabetes without further research. This is a relatively common limitation when using an exemplar case study approach, but as noted by Yin (1994), the benefits of the use of an exemplar case study approach; most notably, being able to examine a relatively unique context and thereby develop awareness and theory to then perform follow up confirmatory analysis, which should not be neglected or sacrificed due to a lack of finding other comparative cases. Clearly then, future research must involve expanding this view and duplicating our initial findings and directional data to provide a more substantive comparison with other potential technology solutions that purport to facilitate self-management for diabetes sufferers.

Another area that will form the focus of future research is to investigate important issues such as the transferability of this solution between different healthcare systems e.g., in USA versus Canada versus Australia. In this way, it will be possible to specifically identify local and global benefits that pervasive technology solutions can bring to chronic disease management. This paper has provided us with many areas for future work. In addition to those areas already mentioned, future work will also be needed to focus on moving forward on designing and developing the necessary strategies for general and widespread adoption of pervasive technologies to support superior self-management as we are convinced this is of critical importance to healthcare delivery.

CONCLUSION

Given the general global consensus that effective and efficient healthcare delivery will only occur through the judicious application of ICTs (News-Medical, 2004; Kulkarni & Nathanson, 2005; Lacroix, 1999; Porter & 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, pervasive technology

solutions like DiaMonD will be even more appropriate, not only because such solutions utilize ICTs to provide superior healthcare delivery in the case of GDM patients, but also because such solutions are both simple to implement and use, and also cost effective both at the micro and macro levels. These levels include individual patients, clinicians and organizations, including public and private healthcare providers.

We set out here to present a case for the need to embrace a pervasive technology solution for the superior monitoring of self-management for women suffering from gestational diabetes in Australia. In so doing, we have also provided a preliminary transaction cost assessment, which highlights the benefits of such a solution. We contend that there is a major role for pervasive technology solutions such as INET's DiaMonD in the context of gestational diabetes and infer that similar benefits should also be realized in the context of controlling both type I and type II diabetes. Further, we hypothesize that pervasive technology solutions are likely to be as effective irrespective of patient's age, socio-economic standing or location, have minimal risks and a very slight learning curve (if at all). Moreover, we speculate that, if pervasive technology solutions such as 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. In addition, it is equally important to note that such pervasive technology solutions can also facilitate the work of governments, healthcare associations, pharmaceutical firms, researchers, healthcare professionals and other key healthcare stakeholders that are looking for improved means and better measurable outcomes among patients suffering from diabetes. Specific benefits range from decreasing diabetes-related complications to reducing the economic burden on the health system.

This paper, then, serves to provide a systematic evaluation of an exemplar case study of the benefits of a pervasive technology solution

to facilitate superior self-management. In so doing, it provides an important contribution to the extant literature in trying to move medical practice and healthcare delivery forward in a number of very vital areas, including diabetes self-management, best practices and pervasive technology solution. In closing, we realize that further research is required to test DiaMonD and other similar software in the Australian healthcare setting as well as the generalizability of such solutions in other context of diabetes both within Australia and throughout the world. However, our directional data to date provides a compelling case for the role of pervasive technology solutions to be incorporated into the treatment of patients suffering from diabetes and we conclude by suggesting that, if pervasive technology solutions are not sought for the monitoring and support of diabetes self-management for both GDM sufferers as well as all diabetes sufferers, then this chronic disease, which is already at pandemic levels, will continue to be a very costly burden for both the healthcare sector and the community at large.

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