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e-clinic: An Electronic Triage System in the Management of Type 2 Diabetes Mellitus

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Abstract

Diabetes Mellitus represents a heterogeneous group of metabolic disorders and its complications are associated with increased morbidity and early mortality. The explosive increase of the number of patients with diabetes, and several recommendations from milestone studies such as the United Kingdom Prospective Study (UKPDS), the Diabetes Prevention Program (DPP) and the Finnish Prevention Study place further constraint on an already overstretched service. This paper examines the care flow process in the current diabetes management and explores the potential role of new technologies and methodologies currently available to support the highly complex clinical requirements. The paper proposes a concept of e-clinic as an electronic triage system with integrated healthcare record, embedded with a decision support system to analyse patients' data and provide a continuous monitoring system according to agreed clinical guidelines.

Keywords:

federated healthcare records, diabetes, workflow management system, clinical guidelines, *e-clinic*

Introduction

The spectrum of disease presentation has changed dramatically over the last few decades. Chronic diseases have now overtaken infectious diseases as the main cause of mortality and morbidity in the developed countries. Chronic diseases present different challenges from infectious diseases. They are characterised by re-admissions for exacerbations of disease or complications, poly-pharmacies, the need for long term follow up and multidisciplinary team management. Traditionally there has been a lack of coordination among providers, and patient education is sporadic, unplanned, and un-coordinated. Discrete healthcare providers often duplicate laboratory and radiological investigations, especially if medical records are not shared.

Over the past few decades however, the framework of our healthcare delivery has changed relatively little in comparison with the enormous changes seen in other areas such as transportation, banking and commerce, manufacturing and telecommunications. Healthcare providers have to find ways to facilitate patient care planning and integration of services. The challenge of integrating knowledge into everyday treatment of a complex and chronic disease such as diabetes is immense. The last few decades have been the era of large-scale clinical trials and molecular genetics. The next few years need to be the era of research into delivering effective healthcare. The effective use of information and communication technology (ICT) has provided a new way in delivering a consistent evidence-based care.

Diabetes Management

Diabetes Mellitus, a disease of small significance to general health a few decades ago, is now becoming a major threat to world health in the 21st century [1]. The past two decades have seen an increase in the number of people diagnosed with diabetes worldwide. The global figure of people with diabetes is set to rise from the current estimate of 150 million to 220 million in 2010, and 300 million in 2025 [2,3].

Diabetes is a disorder of energy utilisation either due to insulin deficiency or insulin resistance, resulted in persistent blood sugar elevation. Diabetes can be further subdivided into categories, but this paper focuses mainly on Type 2 diabetes. Type 2 diabetes is a multifactorial disease that shows heterogeneity in many respects [4]. Globalisation, modernisation, reduced amount of daily exercise, increased caloric intake, and genetic components are the main contributing factors [5]. In recent years, a number of studies have looked at the management of diabetes. The United Kingdom Prospective Diabetes Study (UKPDS) proved unequivocally that intensive glucose control in Type 2 diabetes reduced or at least delayed the incidence of microvascular complications [6]. However, the resources needed to achieve and maintain the UKPDS recommendations are enormous. The initial cost for more intensive treatment is almost three times greater than the conventional management, and involves more frequent outpatient visits [7].

Other epidemiological studies also highlighted the rapid escalation of the number of patients with diabetes and the need for urgent action for its prevention and early detection [8]. Three recent diabetes prevention studies have shown that either oral hypoglycaemic agents [9] or lifestyle interventions [10,11] reduced the risk of progressing from Impaired Glucose Tolerance (IGT) to diabetes by 31% and 58% respectively.

All these findings and recommendations place further dilemma on the current healthcare delivery systems. Over the next few decades, the projected epidemic of diabetes, with its subsequent treatment requirements and complication management will emerge as a major threat to future public health. The complexi-

ties of the healthcare system and the way we manage diabetes care presently have resulted in sub-optimal implementation. The challenge is to provide a fail-safe system of risk reduction and disease surveillance, which promotes patient self-management and life-style control. This paper examines the potential role of currently available ICTs to provide some solution to the challenges.

Current Care Flow in Diabetes Management

Diabetes management has been largely conducted in an outpatient setting either in Diabetes clinic or Diabetes Day Centre. In the current setting of a typical diabetes clinic, data from various sources are brought in together into a single folder. These include patient's demographic details, background medical history, previous consultation notes, medications, cumulative laboratory results and other axillary's reports.

A clinician will review all this information with the patient's recent home glucose monitoring diary. From the data available, the clinician will decide whether or not the patient's diabetes control is stable. Stable patients will be scheduled for a routine review for the next four to six months. Patients who are considered to be unstable or poorly controlled will have their medications optimised and will receive an earlier review appointment date. (Figure 1)

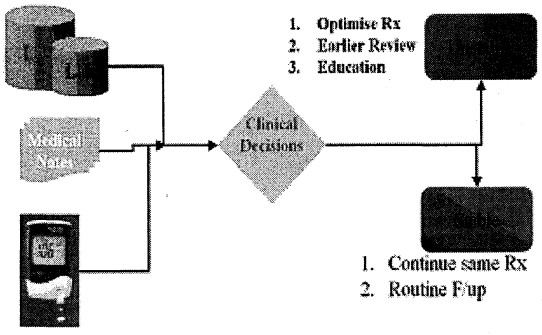

Figure 1 - Current Clinical Care Flow

In addition to existent patients who require regular and continuous care, the number of new patients diagnosed with diabetes is growing every year. One way of meeting these demands is to increase the number of consultant Endocrinologist and the clinic frequency. However, the current way we manage our patients with chronic diseases is unsustainable, even for the wealthiest nations. For example, the Medicare budget (1985-1995) has increased from approximately $50 billion to over $150 billion, and it is estimated that the budget in 2005 will be in excess of $400 billion [12]. These increasing demands and costs will add more pressure and lead to longer waiting lists, compromised standard of care and reduced interaction time between the healthcare professional and the patient.

From our observational study, up to 60% of patients in a particular clinic session are stable. In general these patients need no adjustment to their current treatment, apart from general advice regarding lifestyle changes and dietary measures. However, there is no mechanism in place to act as a triage system to identify and classify this group of patients.

e-clinic: The Conceptual Idea

We define *e-clinic* as "... *enabling the extension of healthcare provision beyond traditional boundaries in current hospital setting, by leveraging currently available information and communication technology...*" [13].

The *e-clinic* acts as an electronic triage or a filtering system to identify unstable patients. A newly diagnosed patient, who has been referred to the diabetes service, will be reviewed at an initial visit to confirm the diagnosis, to receive diabetes education and dietary advice in the Day Centre. The patient will be scheduled on the next available appointment for a review in a diabetes clinic by a clinician. The clinician will assess the patient's progress and determine if further treatment is necessary. If the patient's diabetes control is deemed to be stable and the patient is suitable according to the criteria, the clinician will refer the patient to the *e-clinic* (Figure 2).

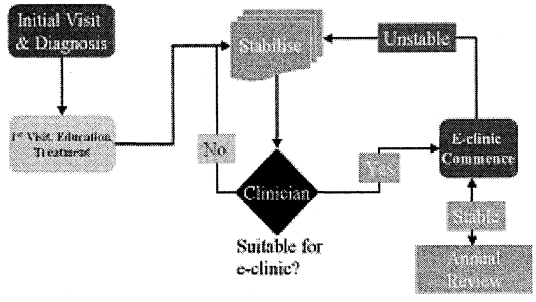

Figure 2 - The e-clinic Care Flow

Patients who have been referred to the *e-clinic* will receive an appointment date for a routine blood test such as HbA1c and further information regarding the *e-clinic*. The patients log on to the *e-clinic* system via the Internet using identity authentication, and are then requested to upload approximately three months of their home glucose monitoring readings from their glucose meter. The *e-clinic* filters out stable patients, by analysing the home-glucose monitoring readings and recent HbA1c result based on defined rules and criteria.

Patients who are classified as stable, will receive feedback from the *e-clinic* system, an HbA1c request form and a follow-up appointment either for another *e-clinic* review or for an annual review in the conventional clinic. However, individual cases that are unable to meet the set criteria to be classified as stable will be discharged from the *e-clinic* register. A senior Diabetes Nurse Specialist or Registrar Grade Clinician will review all these cases at regular intervals. 'True' unstable cases will receive feedback from the *e-clinic* system, an HbA1c request form and an appointment to attend the conventional clinic on the earliest available date. 'False positive' cases e.g. cases with erroneous blood results, will be referred back to the *e-clinic* system.

According to the *e-clinic* protocol, every diabetes patient should be reviewed physically on an annual basis in the conventional clinic to assess overall control, risk factors modifications and complications management. Therefore, patients with poorly controlled diabetes will be reviewed at more frequent interval in the conventional clinic, whilst stable diabetes patients will be seen at least once a year. All transactions and events in the *e-clinic* will be recorded into the appropriate medical record.

e-clinic: System Components & Implementation in *MediLink* Framework

The entire *e-clinic* architecture represents a process of 'technology pull' from technical advancements to accomplish the clinical requirements. The architecture simulates 'typical' weekly outpatient clinic processes but without conventional restrictions such time and physical boundaries. It is an extension of the *MediLink* project framework, an inter-institutional, interdisciplinary research programme in Health Informatics involving researchers in the Dublin Institute of Technology and Trinity College Dublin [14].

The data sources required to simulate outpatient setting are not stored in a single centralized database, but rather are dispersed across a range of standards and formats. These require a federated healthcare record (FHCR) concept, which allows the feeder systems to remain autonomous, but facilitate meaningful sharing of data. This FHCR system is based on a middleware, client-server component-based approach, acting as a common service within the Health Information Systems Architecture. The Synapse server acts as a feeder system to access and merge all the required information from various sources and presents them in a standard format to various specified applications. Each component brings its own added value and has a wrapper that allows independence while providing interoperability with the record server [15].

Outpatient sessions also represent a multitude of processes, activities and interactions within a multi-disciplinary team including administrative staff, hospital porters, nurses, doctors and patients. There is a need for automation or semi-automation to co-ordinate and streamline the care flow processes and activities within a single healthcare system and beyond. The fundamental value of a protocol or guideline is ensuring tasks are carried out uniformly. There is a growing awareness that workflow management tools and techniques can play a vital role in this integration, whilst allowing greater flexibility in care process. A Workflow Management System (WfMS) defines, creates, and manages the execution of workflows through the use of software. WfMS runs on one or more workflow engines, which able to interpret the process definition, interact with other workflow components, and where required, invoke the appropriate applications. Clinical Practice Guideline (CPG) is an evidence-based, recommended practice in healthcare delivery. CPG may represent a specific clinical circumstance, a procedure, an algorithmic and logic, or a declarative rule. Currently, most of the CPGs are in text-based form and not integrated with other clinical care process. This has resulted in poor and slow uptake in actual practice.

Several studies have described different methods of guideline modelling formalisms such as GLIF or EON [16]. However, the *e-clinic* guidelines and workflow enactment utilises an alternative approach by using the mainstream IT business-modelling formalisms. Therefore, the model can be enacted using the mainstream workflow engine, which benefits from huge commercial investment and ever-improving tools. The care flow processes and decision-making components of the *e-clinic* are modelled using Unified Modelling Tool (UML). UML is considered as a de-facto standard for modelling tool and software engineering. Details of the approach are discussed in a separate paper [17]. The model is subsequently translated into XMI, a textual representation based on XML. The XMI then converted into interpretable rules, which form the Care Process Knowledge. The Care Process Engine (Serene) controls the flow of process and sequence of activities through the system by interpreting the Care Process Knowledge (Figure 3).

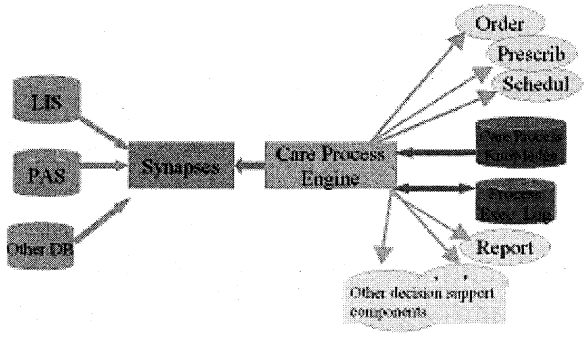

Figure 3 - MediLink Framework

Each activity or event carried out by the Care Process Engine will produce a log. The event log is a temporal or historical data pertaining to the activity or transition state between any two points of the care process. All the logs are stored separately in the Process Execution Log. This information provides an audit trail, and can be used as a monitoring and analysis tool for the management of care process itself.

Most clinical decisions are made from the process of deduction and logic. The challenge here is to translate simple clinical decisions normally made by clinicians into a rule based system as part of the *e-clinic* 'brain'. For our initial prototype, we used a simple rule-based model to classify the cases according to the average of home glucose readings and HbA1c value over certain period of time.

The Internet provides a revolutionary tool with a worldwide broadcasting capability, a mechanism for information dissemination and a medium for collaboration and interaction between individuals and their computers. We use the Internet as our method of communication between patients and healthcare providers. The e-clinic system provides feedback and interactive evaluation of the patients' glucose control. Patient can also have access to their medical records, the results from previous investigations and to be able to compare their diabetes control with the recommendation guidelines at their convenience.

Evaluation

To date, we have proven that the conceptual idea is technically feasible [18]. Our current prototype model is able to classify patients according to the agreed protocol. We are currently testing the safety aspect and robustness of the decision support component with various sample cases. The next stage is to compare the decisions made by the system with ones made by the clinicians with various level of experience in diabetes care. A retrospective analysis has been designed to look at the impact of *e-clinic* system on the management of diabetes care in outpatient setting, such as the reduction of unnecessary visits. Following this, the classification rules could be extended to include more parameters such as lipid profiles, blood pressure and cardiac inflammatory markers. This will provide a more comprehensive review.

Learning is a quintessential characteristic of a clinical skill development. Each case is different and poses different challenges and learning experiences for the clinicians. Consequently, it is interesting to develop a system that also can learn from experience. Medicine has formed a rich test-bed for the machine learning experiments in the past. Machine learning has a huge potential role to play in clinical practice. Given sets of clinical cases such as in the *e-clinic*, a machine learning system would lead to the discovery of new phenomena and the creation of medical knowledge. The next challenges is to see the impact of replacing the simple rule-base model with a more robust decision support models, such as neural network or case-base reasoning with capability of acquisition, maintenance and fine-tuning the knowledge yield from the cases.

Discussion

In comparison with the management of acute diseases, where patients are generally passive recipients of care, diabetes requires a different vision and re-definition of patient-doctor relationship [19]. For diabetes care to succeed, patients must be able to make informed decisions about their illness. It is envisaged that the *e-clinic* system will act as a platform to encourage development of more empowered patients. The *e-clinic* will provide a step towards a more informed and directly-involved patient in the whole management process. A patient empowerment model of diabetes care will allow a patient to choose the most suitable and appropriate time and location for consultation; rather than fixed once-a-week outpatient appointments. An important goal for diabetes care is to enable each person with diabetes to lead the healthcare team involved in the management of his or her diabetes care.

The *e-clinic* also provides an opportunity for a more focused diabetes care management. Only necessary cases are reviewed in the conventional outpatient clinic, while the rest can be monitored through the *e-clinic*. This will reduce the number of patient per clinic session, and subsequently will increase quality time available to spend for patient-doctor interaction. Several studies previously have reported the role of ICT and Internet technology in improving the management of diabetes care. Vie-Diab [20], a telemedical glycaemic control program under Open Clinical Group in Vienna have shown the role of ICT in improving glycemic control of children with Type 1 diabetes (insulin dependent). The MGH (Massachusetts General Hospital) Diabetes Primary Care Improvement Project reported reduction of HbA1c by 0.2%, with improved lipid profile and increased proportions of patients undergoing at least one foot examination per year through their web-based diabetes Disease Management Application [21].

Guideline-based decision support needs to be integrated with useful clinical and administrative applications such as request and order protocol for laboratory and radiology, medications prescriptions, reports and correspondences generating functionality and appointment scheduling. Above all, it should available at the point of care or at least easily accessible during consultation process. WfMS component in the *e-clinic* provides a more robust platform to integrate clinical guidelines and local care flow process in the healthcare delivery system. Evidence based medicine or verified practice such as American Diabetes Association (ADA) recommendations and local protocols can be easily embedded into the system. This will increase compliance among the healthcare providers.

As any electronic patient record and telemedicine project, issue of security and confidentiality need to be addressed. The growth of online banking and e-commerce in the recent past, have provided a better future for telehealth. Secured-Socket Layer (SSL), Virtual Private Network and biometry identifications have a role in providing a more secured environment for data transfer across the Internet.

Information technology is not a drug and should not be evaluated as such [22]. Randomised controlled trials might not be suitable to evaluate the effectiveness of a system. However, there is an obvious need for a regulation and monitoring mechanism before putting any system into practice. This is to ensure the patient's utmost safety and welfare is assured. A legal framework is needed to clearly define the responsibility and accountability of each party involved. Reimbursement issues and online prescriptions also need to be addressed by the policy makers. The *e-clinic* concept calls for a more comprehensive re-engineering of our current framework in order to keep up with the ever-changing healthcare delivery complexity.

Conclusion

Current development and advancements in ICT may be able to provide some answers to the problems of our healthcare delivery system. The *e-clinic* concept may provide an alternative to the Shared-Care or Managed-Care Program in coping with increasing number of diabetes patients. Major transformations in the health care delivery system are required to solve the ever growing challenge of medicine in the third millennium.

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