Development of a Flexible Mobile System for the Remote Management of Chronic Diseases

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Abstract
The cost burden of chronic disease on the healthcare system is one of the major medical and economic issues in the Western world. Efforts to reduce costs and improve the management of chronic disease have focused on the development of programmes that include active patient involvement and information technologies, that enhance the management of patient case and medical data; resulting in a movement toward patient centric healthcare.

The Internet- and Web-based patient support have demonstrated that chronic disease management can be delivered remotely. Although of value in some diseases, the expense, relative complexity and limited mobility of Personal-Computer- (PC-) based systems, confines their use to a narrow range of disease management situations.

We have developed a mobile application platform for the remote collection and management of patient subjective and clinical data. The system uses either Personal Digital Assistant (PDA) or GSM Smartphone patient eDiaries to collect patient data through disease specific applications running on the device. Collected data is transmitted to a WebEDC, an application running on a Web server for processing and further data distribution to call centers, other databases or a Web browser, for review by healthcare providers or additional data entry.

The system is a general platform that can be applied to any disease requiring remote patient monitoring. However, our focus has been on chronic diseases as the area of most need and greatest potential benefit.

We have been running validation studies over the last 12 months in Type I diabetes and are now expanding our activities with partners to include cancer, chronic pain, COPD and asthma. From these validation studies, we will develop a cost effective commercial system that can be applied as a patient centric tool for the management of a variety of chronic diseases.

The Cost of Chronic Disease
Throughout the Western world healthcare costs have escalated. In Europe, Switzerland spends the most on healthcare per capita (11% of GDP) and on a global scale, is second only to the USA [1].

Chronic diseases are the single major cost burden to the healthcare system. In the USA, more than 45% of the population (about 100 million people) suffer from chronic conditions, such as chronic pain, diabetes, bronchitis, COPD, cancer and arthritis, costing society USD 659 billion per year or about 60% of total medical care expenditure [1, 2].

In 2003, healthcare in Switzerland cost about CHF 48,000 million, or about CHF 6,600 per capita, of which the majority was consumed by chronically ill patients [2].

With rising numbers of chronic disease sufferers in an aging population, Western healthcare providers and policymakers are not only facing healthcare financing issues, but must continue to actively transform the healthcare delivery system to better support those at risk or living with chronic disease.

Initiatives to Reduce the Cost of Chronic Disease
According to the CDC, most chronic diseases result from lifestyle choices such as diet, exercise as well as the consumption of tobacco and alcohol [3].

Payers have responded to the increasing cost burden of by developing a range of new healthcare concepts and programmes for both chronic and acute diseases:
Many of these active patient management programmes have been successful in reducing overall healthcare costs. However, the success of chronic disease management programmes is often dependant on the close monitoring and active involvement of patients to modify lifestyle factors and monitor the state of their disease and behaviour [5, 6].

Technology-Driven Movement toward Patient Centric Care

A major trend in healthcare (driven largely by the Internet) is that patients are becoming informed, demanding and empowered to be more actively involved in the traditional healthcare process. While increasing demand for high quality healthcare fuels cost, increasing active patient involvement tends to reduce cost.

An additional trend in recent years is the development and convergence of new technologies in patient diagnosis and self monitoring [7]. This is an interesting development in that medical technologies such as new diagnostics tend to drive cost upwards while new patient self-monitoring technologies and data management applications generally enable cost saving. Examples of the latter are the use of medical call centers, PCs and mobile computers in active patient or disease management.

Together, these trends are resulting in a shift towards cost effective patient-centered healthcare disease management as illustrated below (Figure 1).

Mobile Computers in Chronic Disease Management

Currently, the management of patients with chronic diseases (disease or case management) is mostly carried out through clinical visits or telephone support. With the emergence of Internet technology, PCs have been used in remote patient monitoring and disease management to reduce costs.

However, while PCs have been a proof of principle in electronic disease management (eDM), they are relatively expensive, difficult to use by non-PC users and the elderly. Moreover they are restricted to a single location for data access [8].

In contrast, mobile computers such as Personal Digital Assistants (PDAs) or Smartphones are much more versatile, cheaper, easier to use and deliver anywhere anytime data access. This new mobile technology therefore has specific roles in disease management that cannot be fulfilled by PCs including:

- Monitoring of patient, in-home and out-of-home
- Monitoring and managing patient compliance/persistence
- Remote adaptation/tailoring of treatment according to the individual patient needs and current condition
- Prevention of emergency situations
- Management and early intervention of emergency situations
- A point of need source of information/patient education
- Real life data collection and clinical research.

![Figure 1. Movement toward Patient Centric Care](image-url)
As costs of PDAs continue to reduce and functionalities merge with wireless telecommunication technologies such as wireless local area network WLAN and mobile telephone networks, the PDA or Smartphone will increasingly become a central tool and major cost-saving component in chronic disease management programmes.

Chronic Disease Targets for Mobile Disease Management (mDM)

There have been many publications describing the application of mobile technologies in the management of chronic diseases. However, it is clear that some chronic diseases lend themselves better to the benefits of mobile Disease Management (mDM) than others for both economical and practical reasons:

- Relatively common chronic disease
- High cost disease and identifiable cost items
- High risk/high cost patient groups identifiable
- Measurable short and long term cost savings from mDM
- Diseases where good compliance is critical
- Clearly defined intervention points
- Involve home/self monitoring
- High patient involvement
- High proportion of "young" patients.

Examples of diseases that meet these criteria and most likely benefit from a mDM system would include:

- Diabetes, especially insulin-dependent diabetes (Type I and some Type II)
- Asthma/chronic obstructive pulmonary diseases (COPD)
- Hypertension
- Chronic heart diseases: Congestive heart diseases and Coronary artery disease
- Transplant recipients
- HIV/AIDS
- Chronic Pain
- Cancer
- Palliative care
- Smoking (Smoking Cessation)
- Weight Management.

The Avalis Mobile Patient-Monitoring System

Avalis has developed an electronic system for the remote collection of patient physiological, Quality of Life (QoL) and compliance data via linked medical devices.

The system consists of patient eDiary PDAs linked to a central data processing server via secure Internet connection (Figure 2). Data is transmitted between the server and eDiary via modem, GSM phone, direct connection or Bluetooth, making it very flexible for in-clinic local and distant patient data collection.

The patient eDiary is a generic mobile platform that can be used by patients or healthcare workers to collect and store physiological data through medical devices such as Spirometers, as well as subjective and behavioral data through standard interactive questionnaires audible reminders. The modular design of the eDiary allows the same base eDiary software to be configured to create specific eDiary application (Figure 3).

Collected eDiary data is processed in a Web-based application (WebEDC) running on dedicated server hardware. WebEDC allows the entry of additional patient information by healthcare providers and allows an instantaneous view of patient status and history via any computer with a Web browser.
We have initiated a number of studies using our system in key mDM chronic disease areas. From our studies so far, we are convinced that the remote collection of patient subjective, behavioral and physiological information is not only an important part of disease management, but a key to improvement in the medical treatment and care of patients with chronic diseases.

Improving Patient Care in Type I Diabetes

The support and management of Type I diabetes patients is a complex problem that depends on the monitoring of food intake, lifestyle, exercise, blood glucose levels and insulin dosage.

Patients in France normally visit a diabetes specialist every 3 months by visiting a clinic. Although technically cumbersome to operate, the GlucoNet system was quickly accepted by users and physicians involved in the study. The system has been running for more than 12 months with no data loss or technical support for system errors or failure.

The benefits delivered were as follows:

- Physicians could monitor 50 patients on a weekly level rather than on a 3 monthly level. Greatly improving efficiency and level of patient care.
- Patients felt a much closer level of contact with their physicians and a higher level of care.
- A complete patient history was available over the Internet to all physicians with Web access and permission, easing the problem of patient record sharing.
Long-term improvement in patient outcomes relative to regular care expected, but not yet measured. This system demonstrated the potential of Palm Handhelds and Internet technology in large-scale-patient chronic disease management.

Avalis is involved in the further development of this system by creating patient behavioral compliance and QoL measurement software and Web-based data collection and processing.

Assessing Palliative care in Terminal Cancer Patients

The care of patients with terminal cancer requires not only the control of physical symptoms such as pain, but also the management of the patients subjective and emotional status to optimize overall QoL. Oncology specialists and healthcare providers have great experience in the administration of palliative care to terminal cancer patients. However, regular patient assessment is resource intensive, when patients are at home or only visiting clinics monthly in an out-patient capacity.

At the Bristol Royal Infirmary in the United Kingdom, this process is currently carried out with physical examination and the EORTC QLQ-C30 quality of life questionnaire [10]. The QLQ-C30 is filled out by both patients and healthcare providers to track the patient on a regular basis so the effectiveness of treatment can be assessed.

The processing of the patient information is tedious and error prone: Paper forms are collected and entered into a database manually to construct a patients longitudinal history and QoL. This manual process results in lower patient care due to the following limitations:

- Manual processing limits the number of patient assessments.
- There is a delay between data collection and availability due to manual re-entry into the database. This then delays assessment by the treating physician.
- There are often errors in the paper form responses, these must then be traced back to the patient and/or healthcare provider for correction.

In collaboration with the research group of Miss Jane Blazeby at the Bristol Royal Infirmary (University Division of Surgery) and the EORTC, Avalis has created a QLQ-C30 mobile eDiary and data management system for patient assessment.

The system uses the same basic configuration as that used for the Type I diabetes example above, but the software allows each eDiary to be configured for a single patient user or a multi-user version that registers and tracks many patients for use by healthcare providers in the field or in the clinic.

Unlike paper forms, patient data are validated at the point of data entry, stored in the eDiary and later transmitted to a Web server in Switzerland via a GSM phone carried by the healthcare provider. The collected data is then processed and the complete patient history made available on-line via a secure Internet connection using just a Web browser. Data collected on the Avalis server is automatically processed for uploading into the Bristol database as a batch file for local use. The WebEDC for this project has an additional module that allows the direct entry of patient QoL data through a Web browser giving a single location for all patient QoL data entry (Figure 5). This system is currently deployed and patients are being recruited. Findings will be published at the end of 2004.
Development of a Large-Scale Mobile Patient-Monitoring System

At the recent eHealth.ch 03 conference in Zurich (October 2003), Dr. Dieter Jaepal (IBM) reminded us that the capabilities of devices such as handheld computers and mobile phones will double in memory and screen capacity every 12 months. Indeed we see this with the continual increase in the power of mobile telephones, which now contain many times the memory capacity and features of their predecessors of 12 months ago.

Although the eDiary system described above is functional and suitable for small-scale patient-monitoring studies involving from 50 to 2,000 patients, it would be difficult to develop this system into a cost effective large-scale commercial product, which may have tens of thousands of users. In particular:

- Large-scale hardware acquisition, software installation, testing, deployment and support would drive the unit cost per patient too high to be cost effective.
- The transmission of data from a handheld computer is not seamless and automatic adding the overhead of additional hardware and support of user errors.
- Large-scale data management and security suitable for medical data require a highly efficient and reliable infrastructure.

To circumvent these issues, our approach is to utilize the almost ubiquitous presence of Symbian OS mobile telephones, to contain the eDiary software applications and develop a set of services with a telecom partner to provide secure, scalable and reliable infrastructure. By using this approach, the eDiary data flow can be linked to the Internet and then made available publicly or privately via SSL or VPN connections to stakeholders such as HMOs or call centers (Figure 6).

Testing Large-Scale System in Mobile Chronic Pain Management

Chronic pain remains one of the most common chronic diseases. In Switzerland 1.5 million people suffer from chronic pain, that is often related to musculoskeletal disorders [11]. It is a difficult condition to manage due to the fact that chronic pain is unresponsive to a large variety of medications. Moreover, since pain cannot be measured objectively, treatment is centered on the management of subjective responses reported by the patient.

Patients often become dissatisfied and move from physician to physician in search of relief, making it difficult for the treating physician to assess patient history. Additionally the successful treatment of chronic pain requires a high level of subjective monitoring in order to provide the best level of patient care. This is difficult to achieve when the patient may only visit one time per month with only memories of their pain.

Additionally, patients with chronic pain often suffer from depression. Treatment may therefore require different modalities of coordinated therapy.

In collaboration with Dr. Eberhard Scheuer of the eHealth group at the University Hospital Zurich, Avalis is developing a pilot eDiary for monitoring chronic pain based on the large-scale system design described above.

The initial project will involve approximately 50 patients recovering from surgery where chronic pain is an outcome. The study will use eDiary Smartphones and Palm PDAs containing validated QoL and pain index questionnaires, to assess the patients subjective status and allow physicians to monitor and personalize the treat-
ment of symptoms. Moreover, the system will allow clinical researchers to assess the efficacy of three surgical procedures, reported to reduce the frequency and severity of post-surgical pain.

Data collected from patients will be processed in WebEDC and then exported for automatic uploading to the eHealth data system. Avalis is also in discussion with medical call centers to test data transmission and integration with their patient management software.

As chronic pain is an ideal disease for the development of a large-scale disease management application, the collaborators plan to further develop the system to create a validated tool for mobile disease management.

Conclusion

Rising healthcare costs and rapid changes in communications technology are driving the evolution of new and more cost effective approaches to disease management. Mobile patient-monitoring systems have great potential as disease tools, but they must be user-friendly, technically and economically scalable and deliver an improved level of patient care at reduced cost.

The authors have presented an approach to the development of a flexible mobile patient-monitoring system that is being successfully used to monitor patients suffering from major chronic diseases.

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