Specific Aims

Over 15 million Americans have been diagnosed with diabetes and require medical treatment. In addition, undiagnosed diabetes is estimated to afflict about 6 million more Americans. The U.S. market for diabetes health care is now almost $150 billion, approximately 10% of the United States' total health care budget.

To manage the large number of diabetes patients and prevent debilitating complications, the emerging trend in health care is toward case management by specialized nurses. These specialists monitor the patients' progress and help coordinate scheduling of care provider consultations. While this model has proven itself highly effective, most systems still rely largely on paper documentation and outmoded telephonic technology for patient daily reporting of blood sugar levels and other vitals.

MTP International is developing a lower-cost and higher-efficiency web-based software technology. Web-based technologies have already been demonstrated in the financial sector and have been proven to be reliable, accessible and highly secure. We have completed the proof-of-concept stage, and the system now includes some case management tools and a basic messaging system. However, it still lacks many necessary features and data security measures.

After a physician diagnoses diabetes, the patient is placed on a treatment plan in accordance with established treatment pathways for disease management. In our system, patients receive interactive email reminders when they require treatment or checkups. These alerts are set up in advance by a case manager at the start of the treatment plan. They are automatically generated and our system monitors the patients' responses for adherence. Any issues are flagged so the case manager can intervene. Additionally, the system matches care providers with patients according to insurance type and location.

Improving the current case management system requires revolutionary platform-independent software for patients, care providers and case managers. It must provide secure messaging and automate routine or mundane tasks. MTP's prototype development is a step toward this goal, employing an easy-to-use web interface, guaranteeing platform independence. It also provides a powerful management dashboard for case managers to quantify and track patient progress. The prototype software has undergone preliminary usability testing, detailed in Experimental Designs and Methods. To take this product from proof-of-concept to market, we must fully integrate and demonstrate web security protocols, a patient self-reporting system, and oversight summary reporting. Our specific Phase I goals are:

1. HIPAA Compliance: implement full security protocols.

Implementation of web server and database security, automated reversion to backup, and documentation of compliance with HIPAA requirements. HIPAA security evaluation by an independent source.

2. Patient Data Entry System:

Coding of a data entry system to be used by analysts during the Phase II clinical trial to evaluate the effectiveness of the system. Integration with the patient website interface to create a patient digital health journal.

3. Automated Monitoring and Reporting:

Writing code for audit logs, report generation, and statistical summarization of patient adherence, patient progress, follow-on complications and patient satisfaction. This will reduce case manager workload and simplify oversight efficiency compared to existing systems. It will also satisfy HIPAA auditing compliance.

Phase I will achieve a fully-functional software suite ready for effectiveness and user accessibility testing as preparation for market entry. It will automate much of a case manager's workload, simplify administration, and provide a web-based secure interface for patient daily and new symptom reporting. It will quantify patient adherence and progress, perform statistical analysis of patient data, and generate summary reports.

Phase II will be a full clinical trial involving diabetic patients on case manager run treatment pathways. Our goals will be to demonstrate that our software enables more efficient and lower-cost case management, improved patient satisfaction, and better patient outcomes. We plan to optimize the user interfaces and data presentation in this phase based on user feedback from patients, care providers, and case managers.

Background and Significance

Diabetes: the costliest chronic disease

Diabetes is the single most pervasive and expensive chronic disease in the U.S. The American Diabetes Association (ADA) estimates that the total economic cost in 2007 was $174 billion, up from $132 billion in 2002, a dramatic rise of one-third in only five years. Two-thirds of this was in direct medical expenditures, while almost a third was comprised of indirect costs in the form of lost productivity and permanent disability. Per-capita cost for the nation's approximately 18 million diabetics in 2007 was 2.3 times that of non-diabetics. Furthermore, due to diabetes' increasing prevalence, total costs more than doubled in the same period. As a fraction of total U.S. health care expenditures, diabetes consumes about a tenth.

Diabetes is also responsible for over a quarter million U.S. deaths each year. Even that number is probably low, as diabetes is under-reported as the cause of death. The number of diagnosed diabetics continues to rise by about 1.5 million per year, a disturbing trend that shows no signs of slowing. In 2005, the number had increased to 14.6 million, a 21% jump since 2002. Given this rate of increase, experts predict that one-third of all Americans born in 2000 will develop diabetes in their lifetimes. For ethnic minorities, the grim prediction is one-half. Currently, the incidence of diabetes is not as high in developing countries as in the U.S. and many European countries. However, as these countries adopt western dietary habits, the incidence of diabetes will climb. Ultimately, worldwide healthcare and economic costs from diabetes will be staggering.

The western diet promotes obesity and can cause insulin resistance. This typically evolves into Type II diabetes and its debilitating complications: premature cardiac disease, strokes, blindness, kidney disease, nerve damage, sexual dysfunction, pregnancy complications, dental disease, and peripheral vascular disease resulting in amputations. The detriment to quality of life is incalculable.

Although the ultimate goal is prevention of diabetes, the medical community must treat the existing diabetic population. Current treatment modalities can be effective. They include pharmacological approaches (i.e. ACE inhibitors, insulin pumps), lifestyle interventions (i.e. exercise, diet, and weight reduction), and disease education (i.e. materials from the ADA). Personal physicians, managed care organizations, large healthcare systems, and insurers are assisted by companies providing specialized services. Examples of such companies are Matria (specializing in obstetrics), CHD Meridian (integrated workplace solutions) and Carenet (24/7 call centers). All these interventions help reduce the burden of diabetes. However, their effectiveness is limited by issues surrounding patient compliance and access to care. Furthermore, the most aggressive interventions, which have the best chance of success, are often the most expensive.

Most diabetics have numerous serious co-morbidities which effective treatment strategies must take into account. Overworked physicians, financially strained healthcare organizations and disease management companies are often overwhelmed by the complexities involved in delivery of optimum care to diabetic patients. New approaches utilizing innovative management tools must be designed.

The technological problem

The case management model of chronic disease treatment focuses on education and intervention. The standard paradigm is to follow a treatment pathway, such as that established by the ADA. It mandates care provider consultations at specified points in time, as well as patient daily reporting of vital measurements to determine progress. This generally includes blood sugar and oxygen levels, and blood pressure. A specialized nurse provides oversight and facilitates patient consultations with multiple care providers. Goals include patient education about the treatment regimen (e.g. diet) and diagnosis of follow-on complications in their early stages.

Lack of patient adherence to the regimen is difficult to monitor. The case manager manually reviews the patients' indicators for trends, coordinates and assists with care provider consultations, and adjusts the level of regular patient contact according to treatment progress. Following a pathway generally leads to better patient outcomes than unsupervised treatment. It is, however, an expensive strategy due to technological inefficiencies.

Case management is currently practiced largely without computer automation. Most organizations still use an extensive paper trail to document patient progress. This requires the case manager to collate, pore over and digest a patient's daily reports to identify the overall trend as well as deviations requiring closer attention or medical intervention. On the patient side, daily reporting is made mostly with specialized telephonic hardware devices. While this Telehealth model is an advance over the previous era of handwritten journals, it is not yet optimal. Besides requiring training to use properly, these devices cost approximately $5000-10,000, and are often leased to the patient for $100-200 per month. In addition, both patient reporting of new symptoms and intervention by the case manager require simultaneous availability by telephone. Because this is not easy to achieve, a significant amount of time is wasted simply in one party trying to contact the other.

The two major drawbacks of the existing case management system are the time wasted by the tedium of routine tasks, and the large cost of patient daily reporting. Because of the lack of efficiency, a single case manager cannot oversee very many patients. Our system addresses both of these issues through computerized automation to increase the case manager's task effectiveness, and a computer interface for the patient to eliminate the cost of specialized telehealth hardware.

The MTP case management system

Our plan is to enter the market with a dramatically lower-cost and higher-efficiency approach by replacing this outdated system of paper trails and expensive telephonic hardware with existing web-based software technologies. These technologies have already been demonstrated in the banking and insurance sectors and been proven to be reliable, accessible and highly secure. Most Americans are very comfortable with using the web for many tasks. They are typically also comfortable with communicating via email, as opposed to exclusively by telephone. We have developed a proof-of-concept web-based software system for efficient management of patients using the care provider model.

To improve the efficiency and lower the cost of existing case management practice, several things need to happen. First, routine and/or mundane case manager tasks should be automated, but not at the expense of oversight. Rather, it should enhance oversight and quality of patient monitoring by reducing tedium. Second, interaction between the case manager, patient and care providers that does not require simultaneous contact (*e.g.* on the phone or in person) should be shifted to a secure digital messaging system. All parties may then send or access messages at their convenience. This would reduce case manager time wasted trying to make simultaneous contact on the phone when not absolutely necessary. Third, the case manager should have computer tools which provide a better big-picture perspective of patient progress. These tools should furthermore quantify progress better than existing systems. Fourth, it should provide a level of checks to ensure that the patient understands and follows their treatment pathway, requiring direct intervention by the case manager only when truly needed.

In our system, patients receive reminders when they require treatment or checkups, such as diagnostic testing, consultations, vaccinations, or other care provider referrals. Functionally, to satisfy HIPAA requirements, a patient receives an email over their preferred account simply informing them they need to log in to our system to read their messages in a secure inbox. This is the only reasonable way of achieving encrypted transmission in practice. These alerts are set up in advance by a case manager after diagnosis by a physician, who also establishes a treatment plan such as a standardized plan established by the ADA. The alerts are automatically generated and sent out from that point on.

The MTP system automatically monitors patient responses for adherence to the treatment plan. Any issues with treatment are flagged so that the case manager can intervene. Our system also provides a simple mechanism for case managers to tailor the messages to patients and the treatment pathways according to the subscribing institution's preferences. Also, it has an automatic matching system for care providers and patients according to insurance type and geographic location. Finally, the system design incorporates automated statistical tools to analyze both an individual patient's progress and that of groups of patients, as well as automated report generation for event logs and other audit functions as required by HIPAA. A full description of software functions already completed and those yet to be coded is given in the Preliminary Data section.

Potential market and commercialization strategy

Our initial target market is employer-run health insurance which contracts out or self-manages case management of diabetic employees and dependents. For example, General Motors as an employer, and Davita or CHD Meridian as contracting diabetic treatment organizations. They can reduce costs through the increased efficiency and less expensive technology of our system. They can also improve patient outcomes with our planned rigorous statistical analysis of patient daily reports. When we prove return on investment for employer-run health programs we can also market to insurance companies.

In the short term, our commercialization strategy is to offer our software system to existing case-managed treatment programs. In the long term, we plan to expand by hiring our own case management team, which smaller employer-run health plans could subscribe to. The advantage to them is an economy of scale in contracting out to an established team of specialists.

At about 15 million persons, incidence of diabetes in the U.S. is on the order of 5%. ADP payroll statistics show that roughly 20 million Americans are employed by companies that employ over 500 people. This is our ultimate target market. If we assume that workforce incidence is comparable to that in the general population, we arrive at roughly 1 million working diabetics in our market.

If we assume that about half of employers are willing to pay for the benefits of chronic disease management, and that we can capture half of that potential market, a reasonable estimate is that our system might be used by as many as a quarter million people a year.

A 1999 study by Lisa Ketner with American Healthcorp concluded that management of disease by population (all persons with the disease) rather than management of only the most seriously afflicted (as is currently the case with some disease management programs) would make annual cost savings per patient appreciably greater than has so far been demonstrated. Our system is designed to be pitched at the entire cross-section of an employer's staff, and would be an ideal tool to treat an entire population. Moreover, this study concluded that diabetes is the disease which could save the most money per patient in a system that was designed to treat an entire population.

A 2007 Harvard study by Bu *et al.* described chronic disease management systems as being divided roughly equally into registries, clinical decision support (CDS), and payer-centered systems. The study further suggests that an integrated disease management system which combined elements of all of these would be even more effective. With our plan to monitor patients and to track them as they progress along a pathway with a care provider, our software qualifies as such an integrated system. The study estimated that registries could save about $1016 per year per patient, while CDS type programs could save about $752, and payer-centered systems could save around $558. The estimated cost savings per patient per year of an integrated system was $1180.

Another Harvard 2007 study by Adler-Millstein *et al.* concluded that the annual operating costs of disease management programs vary widely. Depending on the nature of the program, they amount to between $7 and $796 per year per patient.

If we assume that our system can save $1000 per patient per year and there are 250,000 patients who could benefit, the system could produce a total return on investment of $250,000,000 for employers. Our best estimate at this time is that our system can allow a single case manager to support 200 patients. Assuming an annual overhead (including benefits) for such a case manager of around $60,000, we may infer a typical cost per patient, per year would be about $300 to support a case manager working from home. We anticipate the case manager to be the largest financial outlay under our system. If we assume all other costs per patient per year were nearly comparable to those of the case manager, our system could deploy at a cost of about $500 per year per patient, and might save more than $1000 per year, per patient. With a target population of around a quarter million users, our costs would be $125,000,000. With a return on investment of $250,000,000 for a cost to us of $125,000,000 there is an opportunity to produce a profitable business that also improves the health of the population significantly.

Our system appears to be unique and highly scalable and thus suited to rapid expansion. If we assume first year sales of $250,000 (around 500 patients) and a 100% growth rate per year, we will achieve the above goal in about a decade.

Preliminary Studies

Hardware and Software Architecture

We wish to keep costs minimal while not compromising security or reliability. The industry standard for minimizing the technology cost on the server side is LAMP (Linux, the operating system; Apache, highly secure web server software; MySQL, a common high-speed database system; PHP, a dynamic web programming language) on commodity hardware. On the user side, the cost of secure communication is minimized by using a web browser's built-in SSL encryption engine to access the server. That is, every major web browser (such as Firefox, Safari, Internet Explorer, Opera) comes with built-in data encrypting tools which work behind the scenes when a secure web page is accessed; for example a bank account or online store checkout. We adopt this highly successful hardware architecture to minimize cost and maximize compatibility with user platforms accessing the system.

We use JavaScript to enhance the user interface with dynamic web pages. It is extremely robust, fast, and versatile. Similar to SSL, it is also native to all major web browsers – the end user does not need to install any proprietary plug-ins to their browser. This ensures that our web-based system is completely platform-independent and doesn't intrude on the user's personal or institutional choice of browser or operating system.

Implementing such a system over the web requires special attention to data security. Besides using SSL encryption for the web pages, we've designed several additional layers of security. To access the MySQL database we chose PHP, a scripting language often used with web interfaces. It runs strictly on the server side, so the code cannot be viewed or changed by the end user. For this reason, PHP is known to be relatively secure, but we will need additional measures to prevent database corruption or a security breach (Specific Aim 1).

Previous Software Development

We have written a proof-of-concept software package which achieves many of the goals outlined in the description of the MTP Case Management System found in the Background and Significance section. There are five account types based on roles in conventional clinical practice for case management:

- Patient
- Case Manager - manages a group of patients and provides intervention when necessary
- Care Provider - anyone who provides a health-related service to the patient
- Medical Director - designs the specific pathways to be followed by patients
- Administrator - oversees the clinic, admits and discharges patients

Patients are added to the system by a Case Manager, who creates a new account and enters basic patient data. The patient is then automatically matched with Care Providers based on criteria like geography and insurance type. The Case Manager puts a patient on a prescribed pathway, then makes initial contact with the patient by phone to review the process of accessing the web-based system. After this, messages and other routine tasks are automated. Outlier responses to messages and questionnaires trigger alerts for Case Manager response. The Medical Director creates and modifies treatment pathways according to recommended guidelines. The Administrator account has responsibility for admitting and discharging patients, as well as managing the team of Case Managers.

The present suite contains five core modules, most of which are shared by multiple end users, with varying access priveleges. The modules consist of the following:

A. User Interface
B. Pathway Authoring Tool
C. Administration Dashboard
D. Case Manager Dashboard
E. Messaging System

The User Interface is a presentation layer which sits at the top and encompasses all account types. It is a set of routines which organize and create the displayed web pages, including login and account settings. It presents the available functions permitted to the given account type in a menu, and the function of each menu item in a main display when selected. It is thus also an intermediary to other routines which access or modify the database. The account type setting controls whether or not a user can edit displayed information. This code generalization, with varying levels of permission for specific operations, minimizes code size and complexity.

The Pathway Authoring Tool is used exclusively by a Medical Director as an interface to the database to construct and edit treatment pathways which are comprised of various care elements. All care elements are given a time point in the pathway. When the time point is reached, the Messaging system will automatically generate a message to the patient or care provider. The message may be a reminder, educational element, or an automated questionnaire. The Medical Director can also designate a message to require patient feedback via a questionnaire to determine comprehension or adherence. In general, messages will be interactive, as part of the automated monitoring concept. For diabetes, the pathway would generally be the ADA-recommended one. Individual institutions may customize their pathways if they require different preferences or languages.

The Administration Dashboard is the Administrator's interface for managing daily tasks. The Administrator manages the database of insurance and care providers. Administrators can also reassign individual or blocks of patients to a different case manager, including temporarily; for example, when a case manager goes on vacation. Finally, the Administrator processes all patient discharges through the Dashboard. The Administrator account possesses all the functionality of a Case Manager plus additional privileges. Effectively, the two account types share the same code, but with some functionality restrictions on what a Case Manager can do.

What the Administration Dashboard lacks at present is oversight capability: the ability to view summaries of patient progress or problems, including over large groups; and access to audit logs. Specific Aims 2 and 3 will address these deficiencies.

The Case Manager Dashboard is another module that interfaces with the database layer. It provides the big-picture summary of an individual patient. A screen shot is shown in Fig. 1. This unique, information-rich page summarizes all relevant patient information in a single, compact display. It shows patient diagnosis/-es and any co-morbidities in a clinical summary, the assigned treatment pathway(s) and current time position therein, and a documentation spreadsheet which details the treatment pathway. This document spreadsheet also displays the alert history. More detail on any aspect can be brought up by clicking on the relevant item. This grant addresses the need to add additional automated tracking information to this area, such as trend monitoring, summary reporting, and an adherence score for each patient (Specific Aim 3). A case manager also may submit a patient for discharge. This automatically enters an item into the Administrator's queue for discharge review. Patient accounts which reach pathway completion are automatically flagged to the Administrator's queue.

The Case Manager account currently has no means to check on patient progress in a quantifiable way. We need to add automated statistical tools and a module to present the results in a graphical manner. Included should be an automated scoring system for patient adherence and comprehension, based on their interactive responses and those of their care providers. Finally, the module needs a system for recording the Case Manager's notes in free text form. Specific Aims 2 and 3 will address all of these components.

Patient accounts have a very similar Patient Dashboard. In fact it is the same code module as the Case Manager Dashboard, but with even further restricted permissions to only read portions of their information from the database, not modify it. Note that because MTP is *not* trying to function as medical records software, the Care Provider account type is not allowed to access either Dashboard. It interacts with the Case Manager strictly via Messaging.

The system presently lacks a means for patients to make daily reports of their blood glucose levels and other vitals, as well as for nurses or analysts to enter similar collected data during the Phase II scientific clinical trial. It also lacks statistical tools to correlate quantifiable measurements of blood glucose data entered with a patient's progress on a pathway. These are to be addressed by Specific Aim 2.

											Add New Patient
Ser. No.	First Name	Last Name	Email	Day Phone	Clinical Summary	Pathways	Document Spreadsheet	Care Provider Panel	Edit	Close-out Patient
1	Cindi	Sartain	sartains@bellsouth.net	4043942478						X
2	cyndi	simmons	cyndi@creeksidefamilydentistry.net	770466047						X
3	Earl	Gero	ecgero@comcast.net	7083580760						X
4	James	Marciante	jamieisman@aol.com	1234567						X
5	Kenneth	Montgomery	wnm@mtpinternational.com	8472076317						X
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Figure 1: Screenshot of the existing Case Manager Dashboard using mock patient accounts, showing the multiple information summary and management functions described in the text. Specific Aim 2 will address adding color-coded scoring for each patient based on adherence and data analysis criteria, and an additional column which takes the case manager to a detailed analysis page. Details may be found in Research Design and Methods.

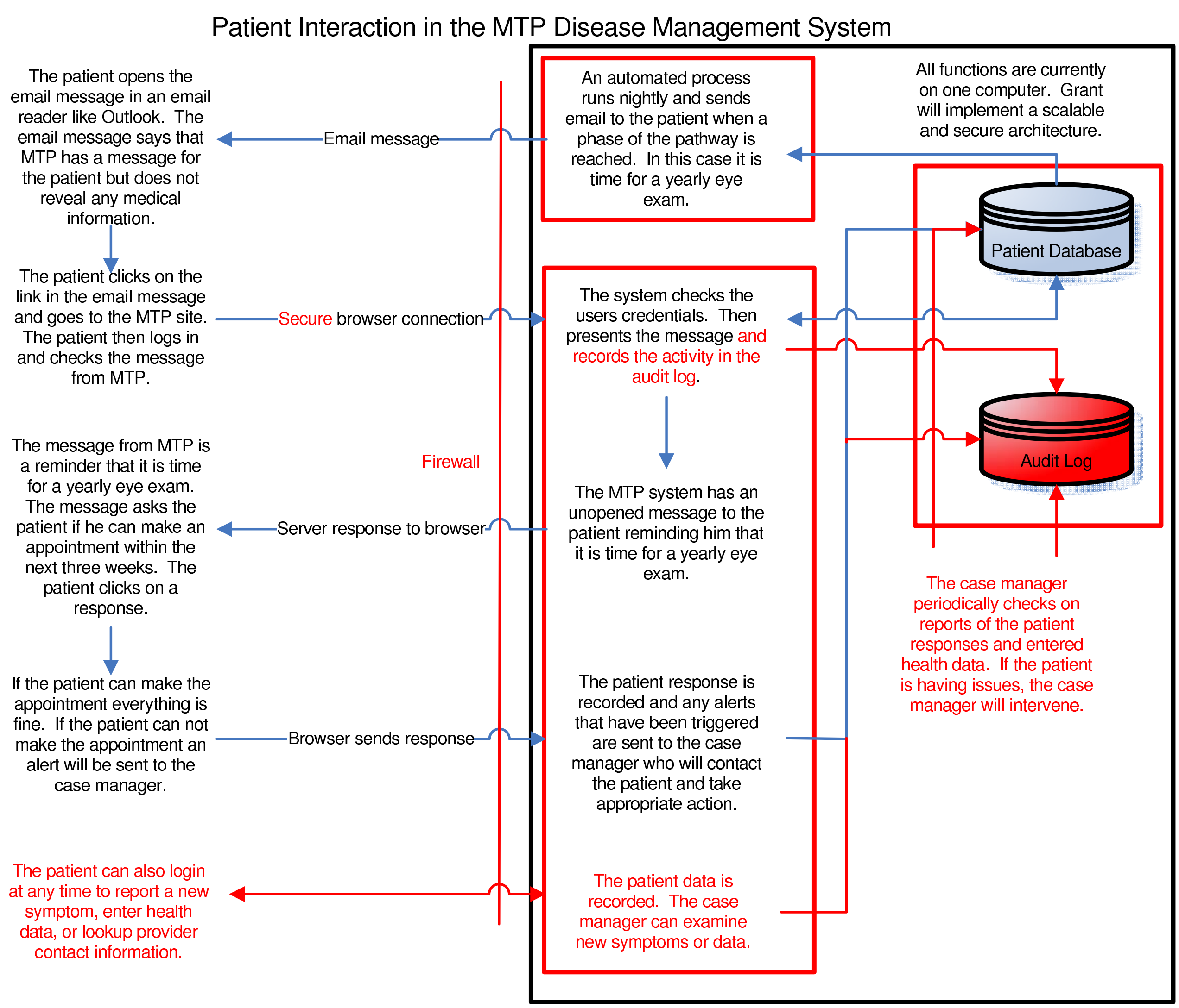

Figure 2: Diagram of the patient interaction portion of the MTP system. Components in red are to be added during Phase I. In order to achieve a secure and scalable architecture, the functions currently on one server will be split into multiple servers as shown. The case manager will be able to view an automated report of the activities and triggered alerts of an individual patient, or of a specified patient population.

The Messaging System has several capabilities. Messages may be automated reminders or follow-up questionnaires, set to go out at specified times in a patient's pathway. They may also be composed messages sent out as necessary by a patient, care provider or case manager.

Automated messages are expected to be the most common. First, form email reminders are sent to patients for the various care elements when their time point is reached. For example, a reminder that their ophthalmology consultation is coming up in two days. The system sends similar reminders to care providers for subscribing patients' upcoming visits. Second, the system sends out a follow-up questionnaire at a specified time after a care element is reached. For patients, this includes brief questionnaires to determine if they're adhering to the treatment pathway, to measure their comprehension of each care element, or to measure their satisfaction with both the system and their progress. Care providers may be asked for feedback on whether or not the patient made the appointment, if they're making progress, and if the care provider thinks that the patient comprehends their part of the treatment program.

Messages may thus be interactive, requiring a response. The response is used to judge whether or not further action is necessary, as well as whether or not human interaction is required. The system automatically alerts the case manager if the patient fails to respond, or gives the "wrong" responses, signifying they require personal intervention.

Finally, both a patient and a care provider may report a new symptom at any time. This is sent to the case manager for review and entry to the database. However, the database is not currently encrypted. Specific Aim 1 will address this need.

Fig. 2 presents a diagram of the patient interaction portion of the MTP system. It illustrates the steps involved in an automated message going out to a patient and how they retrieve it, how a patient enters data on a daily basis, and how the audit logger records these interactions. It also shows a module to be added where patients or personnel may enter patient daily reporting data. Finally, the diagram shows that there is an automated report generation system to be added, which polls the audit logger for specified information to be summarized.

Preliminary Data

To examine the practical usability of the existing software package, we recruited volunteer mock patients and put them on a non-medical test pathway. We recruited diabetics so we could assess the suitability of the site to our target population. Each volunteer was asked to respond to several messages and questionnaires. This tested for errors in the alert response system and gave us ideas for how to improve the current pathway reporting system. At the end of the test we conducted a survey of the volunteers to see if they found the system easy to use and if they would find it useful for managing diabetes. Respondents were asked if they thought MTP would be useful for: sending out general patient satisfaction questions, sending out reminders for medical appointments, asking follow-up questions regarding the usefulness and effectiveness of a consultation or appointment, and sending out comprehension and compliance questions. Responses were generally quite positive but some patients expressed concerns about security. This was expected as the system does not yet implement it.

Research and Development Personnel

The principal investigator for the proposed research and development project will be William Murray, Ph.D. We also propose that the grant support senior programmer Earl Gero, Ph.D., and a graduate student under the supervision of Dr. Mark Braunstein, Prof. of Medical Informatics at the Georgia Institute of Technology.

Design guidance is provided by Janet Huber, M.D., CEO of MTP International. Richard Cross, Ph.D., and David Rainwater, Ph.D., are additional consultants. This team brings together vast experience in all the essential technologies required to implement the web-based secure messaging and health care monitoring system MTP is developing. To recap, this includes large database administration, web servers and secure web connections (Drs. Murray and Gero); user interfaces (Drs. Huber and Rainwater); computer security, secure messaging, and backup reversion protocols (Dr. Cross); and statistical analysis of large multivariate data sets (all programmers, as former physicists).

Dr. Murray has 11 years' experience conducting scientific research and a cumulative 20 years' experience in high-performance computing, database administration, networking and web design. His largest contributions to physics were in the form of large software projects and the experiment's operations management. He authored significant data analysis suites, and the ZEUS collaboration made him one of only 24 lead shift officers (out of over 400 member scientists), with oversight responsibility for all detector operations during beam collisions. In private industry, Dr. Murray worked first in data mining, designing software to search large sets of consumer data for Fortune 500 corporations; then as a consultant and CTO of a web-hosting company. He has extensive experience in web languages and database and network administration. This experience qualifies him to be P.I. of the proposed study.

Dr. Gero also has an experimental physics background in large international collaborations involving multiple institutions. In the private sector his experience is in data mining using models of credit card markets in order to more accurately target consumers. More importantly, he has extensive experience with encrypted databases and secure web transmittal. This experience qualifies him to serve as a senior programmer of the proposed study.

The following persons are involved in MTP, but not proposed to be supported by this grant:

Dr. Cross's experimental physics background lies primarily in statistical analysis of large data sets. His banking industry IT experience in automatic-reversion backup server systems, secure messaging, and system logging will be invaluable in achieving HIPAA compliance. He has further experience in scaling databases, which will be essential as MTP expands its customer database.

Dr. Rainwater is a practicing physicist who specializes in computer simulations involving very large software sets. His work additionally involves extensive statistical analysis of large data sets, focusing on correlations between observables using statistical analysis. This will be valuable for MTP's planned trend monitoring automated tools.

Dr. Huber, CEO, is the originator and conceptual designer of MTP's case management software. She specializes in case management and medical informatics. Her thorough knowledge of these practices, combined with her team's programming experience, is key to MTP's ability to transform and improve the practice of case management.

The following person is not affilicated with MTP, but will be supervising a graduate student performing the security review and code challenge:

Mark Braunstein, M.D., founded Patient Care Technologies (PtCT) in 1991. PtCT provides electronic medical records software to the home health industry. Mark stepped down as CEO of PtCT in 2007 when it was acquired by Medical Information Technology, Inc. He is now working at Georgia Tech's Advanced Technology Develoment Center and will be moving to the Department of Medical Informatics in the fall of 2008.

Research Design and Methods

Proof-of-concept automated case management

The previous work outlined in Preliminary Studies yielded a prototype software suite which automates many of a case manager's routine tasks and streamlines the overall process of case management. It is an improvement over the standard telephone and paper system, which requires simultaneous availability by phone of patient and case manager, even for non-time-critical items. At present the software possesses four core elements:

- Secure messaging between a case manager, patient and multiple care providers.
- Automated message reminders to the patient and care provider according to the pathway's care elements, and automated alerts when the patient does not verify adherence.
- A simple, efficient dashboard interface for administrative tasks. This includes automated matching between patient and care providers based on insurance and locale.
- A dashboard system which summarizes patient diagnoses, pathways, and other useful information.

This software is functional but only proves the concept. It is not yet deployable in the market. We need to code additional software modules for three major aspects to reach that point:

• Data security and HIPAA: While MTP is not in the business of writing medical records software, the Case Manager and Patient Dashboards necessarily display data legally regarded as such. This necessitates security layers at the web interface, and between it and the database.

• Patient data analysis and patient management: To compare our system's results with the results of other disease management systems we need a way to correlate patients with outcomes. This means our software must include a mechanism for entering blood sugar levels and other indicators. Later an integrated statistical analysis package can be run to examine the success of our pathway implementation.

• Automated summary reporting: Replacing the existing outmoded and primitive systems with an easy-to-use web-based system is already innovative. To be maximally innovative, however, there should be automated analysis of the patient daily report data and simple graphical representation of the results. This necessitates additional summary display routines for the Case Manager Dashboard. Thus, we will add content to both the automation and presentation layers.

Specific Aim 1: Data Security and HIPAA Compliance

While we have a proof-of-concept software system running, it has no security measures at all. The requirements in implementing security are multifaceted. First there is the Federal law protecting medical information, HIPAA, from access by unauthorized persons. Second is the need to protect the website against attack by malicious individuals who don't necessarily desire access to data, but wish to disrupt service or hijack the server for other illegal purposes. Third is protection against inadvertent damage caused by legitimate users entering information that the system does not expect. This last is more subtle, but is a general aspect of all databases that must be taken into account.

The first step in implementing electronic security is installing a site certificate for the web server from a trusted authority such as Thawte or Digicert. This is an essential step in establishing an encrypted connection between server and user. It provides the user's computer with a guaranteed means of verifying that the website being accessed is the one the user intended to visit. While this is normally a fairly routine task, we plan to implement an innovative new certificate type which would lower cost and dramatically increase both security and flexibility. Digicert now offers a Wildcard Certificate which covers all web addresses in a company's domain, for $500. This is versus $300 for a single-site certificate. For reasons explained below, we plan to have a separate website for each customer. The business cost for this setup could run into the tens of thousands of dollars per year with conventional certificates, plus additional server configuration work for each instance. The wildcard product would reduce that cost to a nominal $500 per year to cover all websites, and a far simpler server software configuration. How the planned separation of websites ultimately affects security and business flexibility requires some explanation.

MTP's domain is mtpcare.com. Within this domain, we may have an arbitrary number of website names using prefixes, such as www.mtpcare.com, login.mtpcare.com, and so on. In practice, we plan to have a separate website for each institution using our software. For example, diabetic patient employees of General Motors, Allstate and Kraft Foods would log in to gm.mtpcare.com, allstate.mtpcare.com and kraft.mtpcare.com, respectively. This separation is significant, because each website would run a separate copy of the software, and access a distinct database. Separating client databases adds a hard firewall layer of security in the event one database becomes corrupted or otherwise compromised. It would thus reduce negative impact during recovery, limiting any damage or downtime to only a small subset of all users.

Such an innovative scheme has other benefits as well. It guarantees scalability of the business. In contrast, having all users on one database presents well-known problems with scaling that single database to a very large number of users. We would avoid that gremlin completely with this scheme. In addition, it allows us to offer variants of the software based on special customer requests with minimal overhead. For example, if General Motors desired to have an additional feature available to the Case Manager account type, or preferred that Medical Director and Admin were merged, we could provide this easily at minimal cost. Existing open-source version control software can readily keep track of which website uses which version of the software, and upgrades can be handled automatically.

While all major browser developers claim compatibility with wildcard certificates, we need to verify this. In the event that wildcard certificates are not so universal, we would simply revert to the standard scheme of individual certificates for each site, and use multiple web servers. The cost savings compared to existing managed care systems is not quite as great, and more website configuration is required, but our business model would not be in jeopardy. Based on Dr. Murray's previous experience with site certificates and browser compatibility tests, we expect to spend 50 hours to implement and thoroughly test the scheme.

Below web server security is the next layer of the security onion, database protection. This is done at both the software and hardware levels. Currently, the prototype software exists on a single machine, running both the web server and the database. Standard security practice is to separate the two physically, with a web server making read and write requests to another machine hosting the database. Any software exploit used to gain access to the web server gains the attacker only extremely limited data theft potential. He cannot simply copy the database files, since they're not stored on the compromised server. He would instead have to study the PHP code carefully to first understand the database structure, then write additional code himself to pull information out of the database remotely. This would take days, in which time the exploit is likely to have been discovered and the web server shut down. Service would revert to the backup server during intrusion recovery.

To accomplish this architectural change will require server software reconfiguration and some modifications to the database-calling routines of the case management code. It is, however, straightforward, requiring only testing for debugging. This is a low-risk task.

In addition to the architectural change, we must encrypt the password database and protect against so-called SQL-injection. MySQL contains standard functions to encrypt when writing information to tables, and to decrypt when reading from tables. The existing password database calls must be replaced with the encrypting/decrypting versions and tested. Furthermore, as part of password encryption, we need to implement a routine to check for password suitability. That is, a user's choice of password should not be a simple dictionary word which an intruder could guess using automated attack techniques.

SQL injection is a well-known vulnerability of SQL-based databases (regardless of whether the database is open source or Enterprise; similar vulnerabilities exist for all database types). It involves a malicious user typing a string into a database entry field. Certain non-alphanumeric characters are interpreted by the software in ways that can cause the software to produce an error, which can be exploited to gain unauthorized access to the machine. The way to protect against this is to first pass the data entered to a sanitization routine, which checks for special characters which should not be allowed. We plan to combine the sanitization routine with a case-by-case validation routine which checks that the data entered is of the expected type. For instance, a phone number should not contain special characters like &. This is partially implemented now, but requires a stricter level of checks to guard against inadvertent user typographical errors which would unnecessarily consume case manager time to rectify.

Password encryption and SQL-injection protection are also standard techniques and low-risk, but do require time to implement and test. Based on experience, we anticipate these tasks combined to require approximately 150 hours to complete. Our implementation of database encryption and SQL-injection protection will be subject to a code review by a Master's student supervised by Professor Mark Braunstein. We believe that giving a student in Medical Informatics a supervised project to review the database security of the website is an economical way to get a thorough code review. In addition, the student will review the audit system that we design to make sure it is HIPAA compliant. Professor Braunstein's previous experience running a company that developed medical software and extensive knowledge of HIPAA will allow him to provide the supervision that a Master's student needs to provide useful feedback to MTP.

A more involved task is implementing a backup and recovery system, as required by HIPAA. This requires setting up an identical web server running MTP's software, then mirroring the databases. In addition, the backup databases must be synchronized with the master copies on a regular, frequent basis. In practice, this means every few minutes. Software exists to configure MySQL databases to automatically sync in this way, but must be configured and thoroughly tested for every implementation. The router fronting the principal web server must be programmed to redirect traffic to the backup server in the event of the main server's failure. Failure does not mean simply of the hardware or software running on it, however. It includes effective failure due to denial-of-service attacks, or loss of connection at the internet service providers level. (The backup server would be set up at a physically remote location on a different part of the internet.) While it is straightforward to configure web servers to auto-detect any of these failures, we would need to thoroughly test robustness for each of them.

Dr. Cross has set up similar backup reversion systems before, and found it takes typically 100 hours to accomplish the basic programming and testing. In contrast to the partial unknowns of wildcard site certificates, this process is straightforward and routine, but time-consuming. We do not foresee any difficulties with this component.

Federal law requires all entities storing patient data electronically to have a backup and recovery plan in the event of server failure or a security breach. After setting up the system and testing it, we must document our procedure in writing. In addition, we need public disclaimers and other public documents for patients and private policies for the company to bring us into HIPAA compliance. Breakthrough Technologies, Inc. (see accompanying Letter of Support), has a HIPAA Privacy and Security Compliance Guideline document that is geared toward Application Service Providers. We plan to work with Doug Wilson of Breakthrough Technologies to produce our HIPAA compliance document based on his guidelines. He will then conduct a review of this document to identify any gaps in our HIPAA compliance strategy. We expect approximately 100 hours to write our patient and employee policies and make them available to the appropriate audiences. We expect the process of documenting all our policies and participating in the review with Doug Wilson to take about 150 hours. We have allowed another 100 hours to implement corrections to the documentation.

HIPAA also mandates an auditable change log system. We must also include this. Since from a software point of view it is part of a more comprehensive administration system, we discuss this in Specific Aim 3.

Specific Aim 2: Patient Management and Patient Data Analysis

To conduct a useful Phase II study of the effectiveness of our software, we need to be able to gather statistics on the health of the patient population. To accomplish this task we will build a system for entering data like Hemoglobin A1c measurements, and a statistical package for correlating that data to patient's activities on a treatment pathway. An additional benefit is that the data entry package can also be used by patients to keep a personal health journal so they can track their own progress.

Existing case management systems employing the Telehealth model use telephonic hardware for the patient to make daily reports of their blood sugar levels and other vitals (typically blood pressure, and sometimes blood oximetry readings, for example using the Viterion 100 meter). We plan to include this feature. The same code which allows data entry by nurses in a clinical trial can allow patients to enter their daily records directly from the Patient Dashboard.

We see an opportunity to be innovative here. The existing Telehealth systems allow only upload: the patient cannot see data they've previously entered, cannot review their progress except by examining their own written notes. While proprietary software packages exist to perform statistical analysis, we have the expertise to write such routines and integrate them directly into the case management software, as well as routines which present the results in an easy-to-understand graphical form. Statistical analysis would identify both progress trends and sporadic deviations, quantifying in a rigorous manner, for example, how often the patient deviates from a stable blood glucose level. Such analysis would make it far easier for case managers and care providers to identify how well a patient is responding to a certain medication, or how well they're following a restricted diet. Displayed graphically in a simple manner, most patients would be able to understand that their progress trend is good or bad, how often their blood glucose levels stays within their doctor's target range, and how failure to adhere to diet restrictions causes larger blood glucose swings. This is the purpose of the interactive health journal.

The steps involved in implementation break down into three major parts. The first is the addition to the Patient Dashboard which prompts the user to input their daily reporting data and enters it directly into the database. The second is automated data analysis. The third is graphical display of summary information.

Data upload will require a "sanitization" routine as described in the previous section, but with more careful attention to checking that the data entered is reasonable. For example, a blood glucose value should lie within a certain range, not contain non-numerical characters, and so on. This assists the user in making more accurate entries and avoids wasting the case manager's time to check data for gross errors. The patient should also be able to see previous entries from the upload screen in calendar form. This will help to remind them of missing entries, but also constitutes a health journal in electronic form. Previous studies have shown that having these records has a psychological effect, generally encouraging patients to better adhere to the treatment pathway.

Automated data analysis can be performed with a few simple statistical routines, similar to what the software authors have previously used in physics analyses. The proximate goals are to provide summary information on average blood glucose levels and other vitals over time, the standard deviation of swings in levels, and the frequency of swings outside the standard deviation. This is highly innovative, yet is not complicated for the team because of their experience.

Presentation of the summary information should also be innovative. We plan for two stages of implementation. The first stage is to perform a simple and straightforward adaptation of existing Perl script routines to display specified bar-chart summaries of data gathered over many time points. The graphics are not ideal, but are simple and known to work well in all web browsers. This initial effort would require very little time and is essentially guaranteed to be successful. However, our ideal design is a more original graphical strip chart displaying a patient's blood glucose level history (or any other vitals data). It will contain color-differentiated average-value and one-standard-deviation tracks which show the average and fluctuation (stability) trends, horizontal bounds specifying the goal set by the care provider, vertical lines representing the time points of drug or diet changes. The last item would help a case manager understand a patient's behavior, possibly identifying patients who stray from their diet or treatment routine. This design is more informative, but also more complicated, requiring more time to determine how to implement fully. If progress is too slow, we can temporarily set aside this component and use the simpler implementation during Phase II trials.

We have budgeted 200 hours to code the patient data entry and daily reporting system. This part reuses some existing code, but requires expanding the database to accommodate the additional data. Most of the time will be to verify that the database expansion was done properly. For the statistical analysis and graphical display combined we expect to spend approximately 400 hours. Most of that is to allow for the attempt to write new code for a more sophisticated graphical presentation.

We plan for a considerable degree of flexibility to be built into this section. Our intention is to use feedback during Phase II to learn how best to gather, use and present the patient self-reported data. For instance, not all patients will be diligent with daily reporting. The software should allow them to upload previous missed days, up to a point. The patient can receive automated reminders if too many days are missed. The optimal point can be determined in Phase II. Additionally, we should be able to determine, for example, the utility of allowing patients to upload daily caloric intake or other parameters, as an option.

Specific Aim 3: Reporting and Audit System

Specific Aim 2 includes statistical analysis and charting of patient health data, including comparison to a patient's care provider expectations. This information may be used by the case manager and care provider for monitoring, but also by the patient as a health journal. The case manager and care provider could utilize analysis of patient behavior to see not only if a patient is on track, but how well they adhere to their treatment pathway, how often they report new symptoms, how well they understand educational components, and what their level of satisfaction is with the treatment program. Furthermore, the case manager and administrator need to be able to see summary information over groups of patients in a concise form. Such summarization can easily be automated in an electronic system.

This specific aim includes a software module to address this. It is the largest individual component of our Phase I plan, as it is the most extensive and requires the most new code to be programmed. We anticipate and have budgeted 600 hours for this work. In addition to being a highly desirable feature to improve the administrative efficiency of case management practice, it will be integral to the planned Phase II clinical trial. We will require a method during Phase II to evaluate the effectiveness of our software on large groups of patients compared to non-automated systems with fewer patient feedback and behavioral-reinforcing components.

As part of analyzing patient progress, we plan to include automated scoring of patient adherence and progress based on the data analysis of Specific Aim 2. Troublesome patients would be flagged so they receive an appropriate level of additional intervention. That is, those who regularly miss their care provider appointments, have large blood glucose fluctuations, repeatedly indicate a lack of understanding of their pathway directives, or simply fail to respond. Our plan is to color-code the patient entries in the Case Manager Dashboard according to this automated scoring. Detailed analysis will be available on a separate screen, focusing on an individual patient.

This detailed screen will show the various scores and analysis results in several columns. The major components are adherence scores for such items as: scheduling and diet; progress in terms of several measures such as average blood glucose level, stability, and body weight; timeline of follow-on complications; and patient satisfaction.

Part of HIPAA compliance is that an electronic system be auditable. Our prototype software currently has no mechanism to do this. It can read and modify the database, but does not record a history of changes and who made them. We need to write code to perform these functions, as well as code to pull information out of the event logs for review by the administrator, or for a more formal audit. This is conventionally known as log scraping.

The system should be flexible enough to allow log scraping by time or date, account type, individual user, and by the IP number from where the changes were entered. Dr. Cross has extensive experience with log scraping and estimates that such a system can be implemented in a conservative 600 hours. Because an event logger is non-volatile, i.e. a permanent unchanging record, it is far simpler to set up than a database. It is furthermore easier to record a backup copy from one server to another and thus to make the record secure.

After the audit software is designed, we will seek outside review from two sources. A detailed code review and critique of database design will be performed by a graduate student in medical informatics under the supervision of Professor Mark Braunstein. This is part of the HIPAA-compliance code review previously discussed, *i.e.* it overlaps the various Specific Aims. We also plan to collaborate with Breakthrough technologies on the development and assessment of all written security procedures designed to insure HIPAA compliance.

Projected timeline of individual tasks

Based on our prior experience elsewhere with each of the various types of programming tasks required in Phase I, and input from Breakthrough Technologies for the HIPAA audit process, we have constructed a conservative time budget of 2430 total work hours. This forms the basis for our salary request for two full-time individuals for eight months. The time further breaks down into 630 hours for Specific Aim 1, 600 hours for Aim 2, and 1200 hours for Aim 3. The programming tasks are naturally very modular. It is thus straightforward to schedule the tasks serially over the eight months in a maximally efficient manner. We show the work plan graphically in the Gantt chart of Fig. 3.

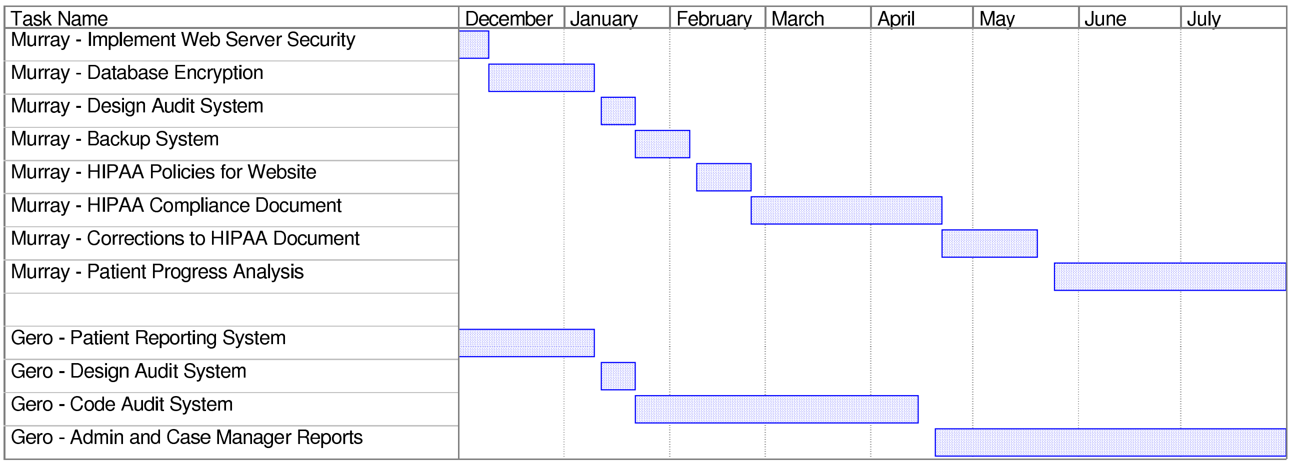

Figure 3: Gantt chart showing the planned Phase I activities of the P.I. and one additional senior programmer. The requested funding would cover eight months of sequential tasks using conservative estimates for time to completion of each task. See text for further details.