HEROS: A PATIENT-CENTERED GOAL-DIRECTED ELECTRONIC MEDICAL RECORD SYSTEM FOR THE HOMELESS

By

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ABSTRACT

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Homelessness is a growing problem in the United States. Numerous barriers keep the street homeless from obtaining healthcare. Medical Street Outreach (MSO) programs are designed to reach out to the homeless. Gathering relevant clinical information on the streets is difficult, and carrying paper records in MSO is cumbersome and inefficient. Several complex healthcare record systems have been developed for hospitals, but no such system exists for collecting health data on the streets. In this thesis, we describe a light weight Electronic Medical Record (EMR), called HEROS (Homeless Electronic RecOrd System) that we have built to address the process of healthcare on the streets. The HEROS system has been designed for use on a Tablet Personal Computer (TPC) to collect, organize, and share clinical data between

clinicians and provide quality healthcare to the homeless. The workflow is based on a novel model of healthcare known as Goal Negotiated Care (GNC), which stresses the needs of a patient on the street, and stresses on small success and the self-efficacy theory. Some major features of HEROS include: (1) Advanced usability features like handwriting recognition, collapsible user interface modules; (2) Communication features like email client and Internet Telephony; (3) Health Level 7 (HL7) compliant Message Passing mechanism for communication with other HL7 compliant EMRs; and (4) Security measures that comply with Health Insurance Portability and Accountability Act (HIPAA) regulations. We will report a field test that has been conducted to evaluate the effectiveness of this system. The design and workflow of HEROS can be easily expanded as a disaster relief EMR or an EMR for emergency situation.

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CHAPTER 1

INTRODUCTION

Homelessness is caused by factors such as housing problems, demographic problems, social disaffiliation problems, mental health problems, substance abuse problems, family violence problems etc [1]. Medical Street Outreach (MSO) programs try and solve as many of these problems as possible, and are not confined to addressing just the medical needs of the homeless, but the social needs too. MSO can take place in a variety of locations such as soup kitchens, in or near shelters, drop in centers, vacant buildings, alleys, encampments, parks etc and their services range from providing information about homeless shelters, housing options, engaging with the patients by offering food, clothing and giving direct medical care. A traditional healthcare approach will not apply to the homeless because of their multiple failures in life. It is also difficult for the clinicians and case managers to use paper records during clinical outreach.

1.1 Electronic Medical Record (EMR)

An electronic medical record is a medical record in digital format and facilitates the following:

1. Access to patient data by clinical staff at any given location
2. An increase in liability coverage
3. Accurate and complete claims processing by insurance companies

4. Building automated checks for drug and allergy interactions
5. Standardization of care pathways and protocols
6. Clinical notes
7. Prescriptions
8. Scheduling
9. Sending to and viewing by labs

Electronic records in health fall under the purview of health informatics, a combination of computation and computer science and medical record keeping.

According to the Medical Records Institute [2] five levels of an Electronic HealthCare Record (EHCR) can be distinguished:

1. The Automated Medical Record is a paper-based record with some computer-generated documents
2. The Computerized Medical Record (CMR) makes the documents of level 1 electronically available
3. The Electronic Medical Record (EMR) restructures and optimizes the documents of the previous levels ensuring inter-operability of all documentation systems.
4. The Electronic Patient Record (EPR) is a patient-centered record with information from multiple institutions
5. The Electronic Health Record (EHR) adds general health-related information to the EPR that is not necessarily related to a disease

In this thesis we concentrate on building a level 3 EHCR which can be extended to a level 4 or level 5 based on needs.

1.2 Goal Negotiated Care (GNC)

Boyce [3] suggests that the tendency towards victim blaming, particularly of homeless individuals, has created structural influences and constraints on the participation of these groups in the healthcare process. In general, the rules, values, attitudes, and activities of health-care and service organizations are designed to limit the input of individual consumers by placing them in a position of passivity and powerlessness in relation to that of the service provider. This learned helplessness and resulting disengagement may be an anticipated result of homelessness and the simultaneous loss of hope, which creates a self-perpetuating cycle of hopelessness, low self-efficacy, low self-esteem, and depression [4]. Similar responses have been seen in those who have experienced traumatic disruptions in their lives [5]. By intervening in the cycle of hopelessness, the health-care professional can help restore self-efficacy, raise self-esteem, and ease depression [4].

The theoretical construct of self-efficacy has been used widely in public health programs and interventions [6, 7] and more recently in medical practice [8, 9]. The premise behind the construct is that greater confidence in performing a particular behavior makes it possible for an individual to change unhealthy or risk-taking behavior (i.e., reducing fat intake or stopping cocaine use) and become more engaged in the health-seeking process. The Self-efficacy theory suggests that any such change made by the individual will lead to an improvement in the health outcomes. Goal-negotiated care

(GNC), a locally-based implementation driven by the self-efficacy theory and patient-centered care, was developed for the homeless and entails more than just changing a homeless person's risky behavior. GNC engages homeless patients in a different way. With the addition of self-efficacy as a guiding principle, GNC is the first effort to focus on the homeless patient's need to experience success working with others and to reinforce his or her efforts to reengage with society.

1.3 Need for a GNC based EMR

Further complicating the care of homeless patients is the perceived need of many homeless persons to remain independent and to protect their space. This perception often keeps them from going to shelters or clinics or from forming affiliations with any organization or small group. Such a transient lifestyle makes the homeless very difficult to evaluate and track over time in terms of adequate health-care provision. In an effort to provide basic health care to homeless patients and to develop a trust relationship, providers need to meet their patients' primary health-care needs through outreach on the streets [10]. For this reason, medical street outreach has become a common feature of numerous community health service programs. Clinicians provide basic or triage care to homeless individuals in settings as diverse as soup kitchens, on the streets under bridges and overpasses, and in shelters [11]. This outreach is undertaken to improve the health of homeless patients and to encourage the utilization of human services and health-care resources. Other high-risk populations have shown a similar need to be "met on their own turf" [12]. For this reason, building

an EMR that is both portable and lightweight is a great need for outreach medical program.

1.4 Contributions

Traditional EMRs and EHRs, like General Electric's Centricity, are complex client server systems that are not portable, very expensive, and follow a clinician driven workflow. There are no portable, light-weight EMRs currently available in the market, which serve the needs of street medicine.

Our contribution is a new EMR called HEROS (Homeless Electronic RecOrd System), which is inexpensive and can be use for street medicine. The new system is patient driven and designed around the Goal Negotiated Care workflow. The system runs on tablet personal computers, and can easily be integrated with more complex systems. We have also conducted a case study to evaluate the system.

1.5 Thesis Organization

In Chapter 2, we discuss the background concepts, use of paper records and handheld devices. We also discuss related work to justify the design decisions explained in our description of the system. In Chapter 3, we present our proposed system in detail and analyze the features and functionality of the system. In Chapter 4, we explain the implementation process, a comparative study with Centricity (a complex EMR currently used at hospitals and clinics), and a case study of the Implementation of HEROS at Healthcare for the Homeless-Houston (HHH). In Chapter 5 we conclude the thesis, and provide ideas for future work.

CHAPTER 2

BACKGROUND

2.1 Paper Records

Use of EMRs and other health technologies in the United States have been minimal. As of 2006, less than 10% of American hospitals have implemented health information technology [13], while a mere 16% of primary care physicians use EMRs [14].The vast majority of healthcare transactions in the United States still take place on paper, a system that has remained unchanged since the 1950s. The healthcare industry spends only 2% of gross revenues on HIT, which is meager compared to other information intensive industries such as finance, which spend upwards of 10%.[15] The following issues are some of the major causes of this slow rate of adoption.

2.1.1 Interoperability

In the United States, the development of standards for EMR interoperability is at the forefront of the national health care agenda [16]. Without interoperable EMRs, practicing physicians, pharmacies and hospitals cannot share patient information, which is necessary for timely, patient-centered and portable care. At present a large number of vendors producing EMRs, manufacture software that is customized for an organization and have no interpretability between each other.

2.1.2 Addition of old records to EMR

To attain the wide accessibility, efficiency, patient safety and cost savings promised by EMR, older paper medical records need to be incorporated into the patient's record. The process of converting these paper records into digital format is an expensive and time-consuming process. Because many of these records involve extensive handwritten content, some of which may have been generated by different healthcare professionals over the life span of the patient, some of the content is illegible following conversion. The material may exist in any number of formats, sizes, media types and qualities, which further complicates accurate conversion. In addition, the destruction of original healthcare records must be done in a way that ensures that they are completely and confidentially destroyed.

2.1.3 Privacy

Privacy is a very big concern when it comes to electronic records. It has been estimated that approximately 150 people (doctors, nurses, billing clerks, technicians) have access to some or a part of a patient's medical records during one hospitalization and about 600,000 payers, providers, and personnel handling billing data also have access to the same [17].Multiple access points over an open network like the internet increases possible patient data interception. In the United States, this class of information is referred to as Protected Health Information (PHI) and its management is addressed under the Health Insurance Portability and Accountability Act (HIPAA) as well as many local laws [18]. Newly emerging technologies like wireless networks have offered more challenges to security.

2.1.4 Social and Organizational Factors

According to the Agency for Healthcare Research and Quality's National Resource Center for Health Information Technology, EMR implementations follow the 80/20 rule; that is, 80% of the work of implementation must be spent on issues of change management, while only 20% is spent on technical issues related to the technology itself. Such organizational and social issues including restructuring workflows, dealing with physicians' resistance to change, play a major role in slowing the rate of adoption of EMRs to paper records.

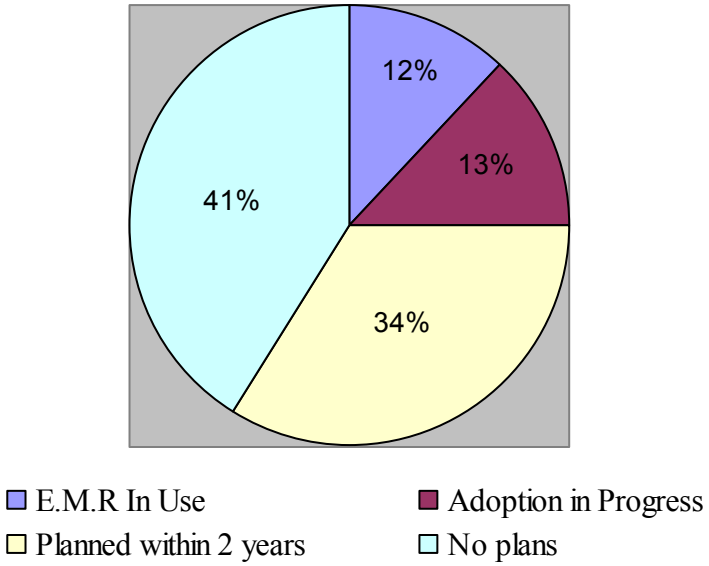

Figure 2.1 US Medical Groups adoption of EMRs

2.2 Handheld Technology

There are plenty of examples in the medical and technology literature about the merits of handheld computers, or personal digital assistants (PDAs), in medical practice [19] [20]. PDAs offer greater mobility and flexibility and can improve the efficiency

and accuracy of clinical tasks [21]. Eliminating the need for the transcription of notes into patient files means that clinicians can spend more time in direct patient care, which could lead to an improvement in the quality of care that patients receive [22, 23]. Two-way synchronization allows the creation, update, and deletion of patient records from any location [24]. The researchers are aware of only two programs in Boston, MA, and Pittsburgh, PA, in which PDAs are being used for any data collection on the streets with the homeless. Neither site has invested in software loaded with an innovative model of care.

CHAPTER 3

SYSTEM DESIGN AND IMPLEMENTATION

3.1 Overview

The HEROS system is data-centric application with the following 3 factors playing a major role in its design.

3.1.1 Usability

The HEROS system is designed to be used on the streets, while talking with a patient or while the patient is having a meal or is working. This requires that application to be designed in a way that makes it easy to access and maneuver. The hardware currently being used to support the application is the LS 800 series Tablet PCs from Motion Computing. They have a viewable screen dimension of 8.4 inches and perform best at 800 x 600 pixel resolution. This makes the real estate for viewing a major issue. To solve this problem, we have designed a collapsible control and have made use of tabs. Using these controls can cause a very complex user interface making the system a problem rather than a solution. We have thus maintained the user interface design to our rule of 'Three clicks to any item'. By this we mean that it takes maximum 3 clicks for a user to go to another part/menu or item, from the point where he is currently in the application.

3.1.2 Expandability

The HEROS system was tested at Healthcare for the Homeless-Houston. It proved to be a major success there and is being used extensively for the benefits of the homeless. Apart from Healthcare for the Homeless-Houston, plenty of other organizations have shown interest in the system. We got positive responses from 20 other sites across the country and globally, who want to implement this same idea. The HEROS system can also be used for emergency application or in a disaster relief scenario in future. This requires the design of the system to be expandable and customizable in nature.

3.1.3 Flexibility

Medical informatics is changing everyday and new technology and hardware is being introduced into the market frequently. The HEROS system has been designed keeping in mind such changes. The system has been designed into modules for flexibility and maintains a layered structure differentiating the application, the business logic and the data layers. This provides a system that can be modified or changed easily and maintained efficiently.

3.2 GNC Design and Workflow

Past outreach efforts on the streets of Houston, TX, by Healthcare for the Homeless—Houston (HHH), involved handing out lunches and encouraging homeless individuals to seek health care at established clinic sites. This impersonal approach did nothing to encourage patients to seek future care or to return for follow-up care with the van. The medical director of the program, a member of the research team, drew on his

clinical experiences during medical outreach to develop goal setting with patients. The GNC model was conceptualized and operationalized into a program for handheld computers. The PDAs became a convenient mechanism for initiating GNC as the standard of care during street outreach. Using a collaborative approach to goal setting, the outreach team toured the streets to increase goal setting, engagement, and self-efficacy among the street homeless through a more efficient workflow. In addition, clinicians attempted to remove care barriers and empower homeless patients to make decisions regarding their own health by negotiating goals. The ultimate benefits of the technology were the ability to track and follow up on goals negotiated with each patient, as well as the capability to share information among clinicians.

During the first stage of the project, the physicians and family nurse practitioners (FNPs) that provided the outreach services were able to record the entire encounter on-site, including demographics, patient history, medical diagnosis, and goals. Upon completion of the clinical encounter, the clinicians negotiated goals with the patients that would meet their particular healthcare needs. All follow-up encounters included goal assessments from previous encounters to determine if goals were completed. Unfortunately, the PDAs proved incapable of storing the large database and the use of this technology was discontinued [25].

With feedback from the clinicians and FNPs using the PDAs, the core of the program—the GNC logic model was subsequently developed. Regular meetings over several months to brainstorm the program logic led to the creation of a schematic representing every foreseeable permutation of the care process. What emerged through

this iterative process was a prototype based on the five "W"s: who, what, why, when, and where (see Figure 3.1). The new GNC allowed clinicians to easily navigate through a care encounter.

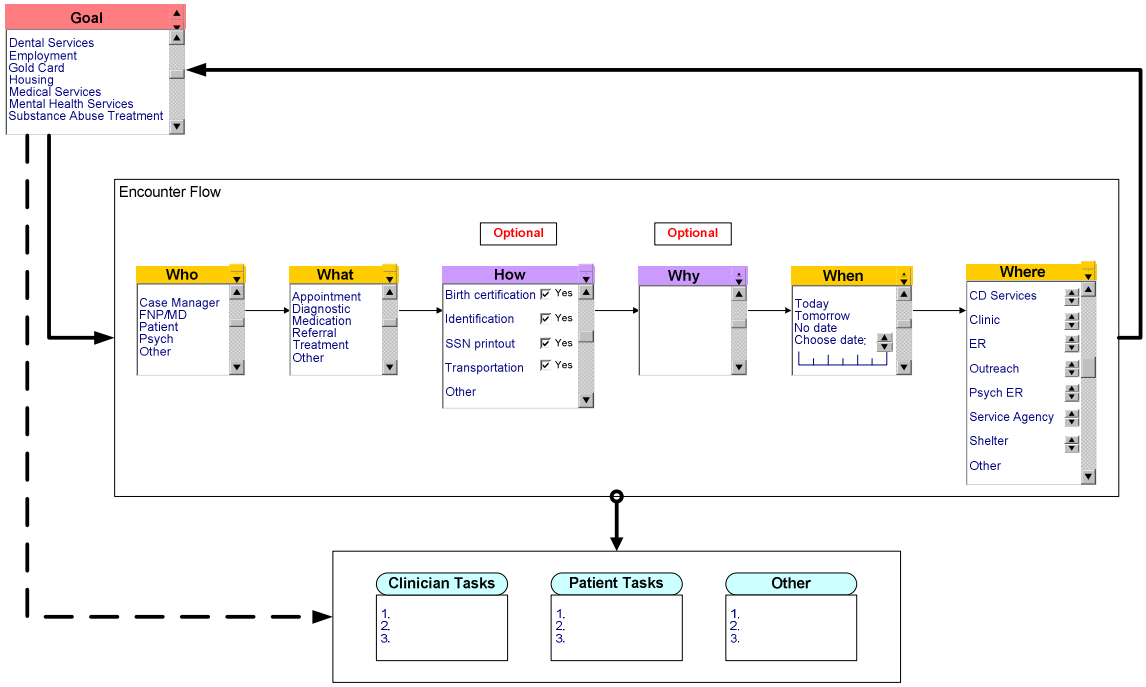

Figure 3.1 Logic Flow Model for Goal Negotiated Care

In a traditional, problem-based clinical encounter, the clinician tends to move linearly from patient history to diagnosis and treatment; tasks for patient and provider occur as the outcome of the encounter. The most attractive feature of the GNC model is the ability to navigate between goals and tasks in a bidirectional manner. One approach, using GNC within a traditional care encounter, involves identifying the problem, formalizing goals with the patient, and assigning tasks for both. For example, a patient presents complaining of lower back pain, the clinician collects a brief history, completes the exam, and demonstrates some pain reduction exercises; a date is then set for a return

visit. With the alternative approach, the clinician uses the patient goal as the starting point then moves backward or forward through the who, what, how, why, when, and where components; the system identifies the required tasks as the need arises. The value of the system is the flexibility it gives the clinician and patient to change approaches "on the fly." To illustrate, the patient begins by saying he wants to obtain employment, but lower back pain prevents him from holding a job; the clinician demonstrates some pain reduction exercises and makes an appointment for the patient to see the case manager about job opportunities. The TPC program reminds the clinician to schedule a follow-up appointment in addition to generating a reminder for the patient about his appointment dates. The entire process becomes much more interactive for both clinician and patient, empowering and building the patient's self-efficacy by addressing his/her specific goals and tasks.

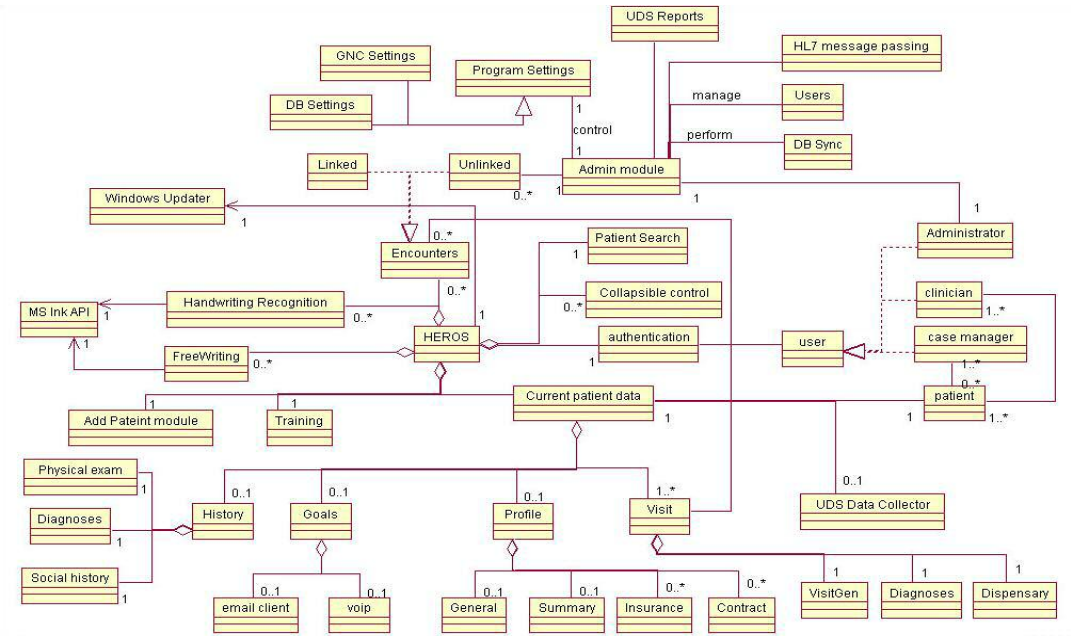

Figure 3.2 Domain Model of HEROS

The high level domain model design as shown in Figure 3.2 describes the different entities of the system. A detailed description of the entities is covered in subsequent sub-sections. A diagrammatic representation of the system architecture is shown below in Figure 3.3

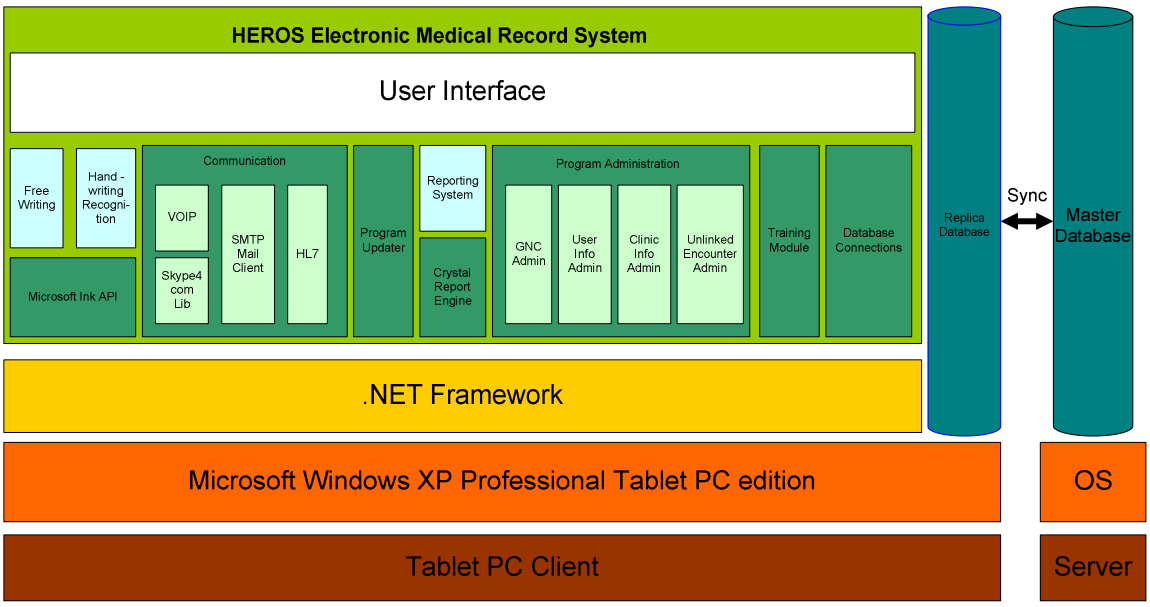

Figure 3.3 System Architecture of HEROS

The HEROS EMR runs on tablet PCs that run on Microsoft Windows XP Professional Tablet PC Edition. HEROS is built using C# and runs on the .NET framework. The different modules are shown in the architecture diagram above. The free writing and handwriting recognition modules make use of the Microsoft.Ink API that comes as part of the Tablet PC software development kit. The communication module consists of Voice over IP that resides above the Skype API [26], an SMTP mail client for communication through email and the Health Level 7 (HL7) interface for communication to other EMRs.

The program updater is a small module that runs every time the system begins to shut down and checks a web server for updates. If an update to the program is available, it downloads the required files and installs them. The reporting module is built using Crystal Reports for .NET and runs on the Crystal Reports engine. The program administration module consists of four sections – GNC Administration, User Information Administration, Clinical Information Administration and Unlinked Encounter Administration. The training module consists of videos that walk through the program workflow and explain the main functionality. It consists of four videos of 80 minutes of training material. The database connection module is generic in nature and is used for connection to multiple databases. A replica database exists on the tablet PC and syncs with the master database, residing on the server, during startup and shutdown. Each of these modules is explained more elaborately in subsequent sections of this chapter.

3.3. Graphical User Interface Design

As we mentioned in the previous chapter, usability is one of the major factors in the design of the HEROS system. A clinician should be spending least amount of time trying to enter information and maneuvering through the program, and more time in the actual success of an encounter. A tablet PC can be difficult to use, especially with regard to text entry. Another major problem with tablet PCs is the amount of real estate for viewing the application. Fitting all the fields for data collection on a tablet with a viewable screen of 8.4 inches is very difficult and can cause extensive clutter of items on the screen.

To solve these problems we have developed a number of useful features and incorporated them into the application to make it as user-friendly to the clinician as possible, and in turn reducing the time they spend trying to find menus and enter data. The following are the main features:

3.3.1 Tab based view

To fit all data input items into the screen, they have been categorized into 4 categories namely, Profiles, Goals, Visit and History. Each of these categories are further divided into sub-categories. Each category is a different tab page and the subcategories for a particular category are tab pages within the tab page for that category. Data fields for every subcategory are placed within the tab page for that subcategory. This kind of tabbed view serves dual purposes, firstly it enables us to categorize related data fields into common categories and subcategories giving the EMR a more organized feel, and secondly it enables us to fit a large number of data fields on a small screen size, which would otherwise not have been possible without having to use multiple forms. A tabbed view is preferred to multiple forms as multiple forms not only increase the design complexity, but also make the application a lot more confusing and difficult to maneuver in.

3.3.2 Collapsible sections

Even after using tabs, we found the application difficult to use. This was because each tab still had a lot of data fields within it making it cluttered and difficult to find a particular item. To solve this problem we created a new collapsible control within each of the tabs. This control can be collapsed and expanded giving us even more real

estate to work with. The data fields were further subdivided based on the properties of similarity and priority, and placed within different collapsible units within a tab.

3.3.3 Color coding

To further improve the speed of data entry, we have differentiated UDS data fields and non-UDS data fields using white and yellow backgrounds respectively since the basic information that must be entered for any patient is the UDS information.

3.3.4 Handwriting Recognition for Numeric Fields

Data entry on a tablet PC is extremely difficult, and using the Windows inbuilt input panel can be difficult at times, especially with trying to correct mistakes in handwriting recognition. To improve this we have built our own handwriting recognition control for numeric fields. This control is much more specific in nature when compared to the more generic Windows input panel, and can be formatted based on the type of numeric field. This is further explained in the Figure 4 of Appendix B. From Figure 4, we can see that each block represents one numeric character that can be entered. This reduced area, and the possible number of characters being just 12 (0 to 9, -, and .) increases the probability that the handwriting recognition algorithm will return a desired value, when compared to the Windows inbuilt input panel. All numeric data fields in the HEROS application have this feature, thus improving the speed of data entry.

3.3.5 Free writing Notes

HEROS has a free writing module that is used to enter notes as free handwriting using the stylus. This notes field is present in most subcategories of the application and

is useful for taking down notes when in a hurry. The data is stored as base 64 encoded data in the database, and the writing is regenerated using the Microsoft.Ink API. Since the program does not have features yet that will convert the data into readable test, it is best to use this feature only during time critical situations.

There are a number of other significant features in the user interface design like automatic dropdown timers for combo boxes, which will show the contents of a combo box if the stylus hovers over the control for a particular time period, helper icons throughout the program that explain functionality of a control and guide the user when clicked, etc. These features too, improve the overall usability of the application.

3.4 Database Design

The HEROS system has been designed keeping client flexibility in mind. Since a number of organizations are interested in the application and each has different budgets, we have supported multiple database systems. Initially, we used Microsoft Access as the database system, then expanded to MySQL 5.0 and Microsoft SQL Server 2005. A large part of the application's logic is database driven. This is especially true for the GNC module. Run time decisions are made based on entries in the database.

3.4.1 Database Replication

The HEROS system is designed and built to be used for outreach program, where connectivity may be an issue. To maintain data integrity, we have made use of database replication, which is a way of keeping data synchronized in multiple databases.

3.4.1.1 Replication using Microsoft Access 2003

Each tablet has an instance of Microsoft Access Database running as a replica. Each time the application loads or shuts down, the system tries to connect to a master database that resides on a server and synchronizes itself. The system also allows manual synchronization from the administration module. This way, we try to maintain data consistency.

There is a high probability that the information on a tablet PC that is taken out on outreach may not be consistent. To reduce such inconsistencies in data, we decided to have a rule in the organization that every Tablet PC must be synchronized before and after outreach. There is still a possibility of data inconsistencies caused by human error. To reduce this problem, we setup a wireless network connection in the site that is visited most frequently by clinicians, and switched from pure distributed replication to a hybrid system, which used both replication and a client-server database architecture, where a client connects directly to the server's database.

Now, when the application starts up, it checks for a network connection. If it finds one, it tries to connect to the master database on the server, else it will connect to the replica database on the client (tablet PC). An Access database was not suitable for this purpose due to Microsoft Access's inability to handle concurrent connections from clients. To solve this problem, we used two other database systems – Microsoft SQL Server 2005 and MySQL 5.0.

3.4.1.2 Replication using Microsoft SQL Server 2005

In Microsoft SQL Server replication, there are two main components:

Publishers have data to offer to other servers.

Subscribers are database servers that wish to receive updates from the Publisher when data is modified.

In the HEROS application, the tablet PCs act as both publishers and subscribers. Microsoft SQL Server supports three types of database replication namely Snapshot replication, Transactional replication and Merge replication [27]. In this application, we have configured the database servers to be used as Merge replicas. The tablet PCs run Microsoft SQL Server 2005 Express edition, and the server has an instance of Microsoft SQL Server 2005 Enterprise Edition running on it.

3.4.1.3 Replication using MySQL 5.0

MySQL supports two kinds of replication, the first is a one-way, asynchronous replication, in which one server acts as the master, while one or more other servers act as slaves, and the second is the *synchronous* replication which is a characteristic of MySQL Cluster.

In our system, we make use of MySQL server's asynchronous replication feature. MySQL replication is based on the *master* server keeping track of all changes to the databases (updates, deletes, and so on) in its binary logs, and *slave* servers connecting to the master to get queries to update itself. In our system, instances of MySQL on the tablet PC and on the server are configured to act as both master and slave.

Replication using Microsoft SQL Serve 2005 and MySQL 5.0 is currently being tested at the Palmer Way Station site.

3.5 Data Collection

One of the primary goals of the program is to be able to collect as much information about a patient in the least possible time. This becomes a major requirement due to the psychology of a homeless patient. Having experienced so much failure in their life, they begin to think that almost nothing is worth waiting for. A wait longer that 2 to 3 minutes will become unbearable to them. The system has been designed to bring to the attention of the clinician primary data that is required for UDS reporting.

The data collection may be classified in two ways:

1. Based on the type of data there are three major categories which are Demographic data, Clinical data and GNC Data
2. Based on data for reporting purpose there is Uniform Data System (UDS) required data and non-UDS data

3.5.1 Demographic Data

Any kind of information that is obtained from the patient with regard to demographics, such as name, age, sex, gender, ethnicity etc. is considered as demographic data. We collect a large amount of such data for future research and statistical analysis purpose. There is also a need to capture non-traditional demographic data like body art, physical features etc, which may be used in future to identify patients who are unwilling to give away primary identification information like name and social

security. This again is a common phenomenon among homeless patients due to their constant struggle on the street and the lack of trust.

3.5.2 Clinical Data

We consider information that is collected primarily for patient healthcare as clinical data. This can be diagnosis, dispensary information, patient's clinical history etc. This is critical information that is require for treatment purpose.

3.5.3 GNC Data

We consider any information that is generated based on inputs from the GNC module as GNC data. This will include information such as goals that have been achieved by the patient, pending goals, tasks for a clinical or patient for a particular goal etc.

3.5.4 UDS Data

Health Resource and Service Administration (HRSA) collects core information through the Uniform Data System (UDS) appropriate for monitoring and evaluating health center performance and reporting on trends. UDS collects basic demographic information on populations served, such as race/ethnicity and insurance status of patients. The data is analyzed to ensure compliance with legislative mandates, report program accomplishments and justify budget requests to the U.S. Congress. The data helps to identify trends over time, enabling HRSA to establish or expand targeted programs and identify effective services and interventions to improve access to primary health care for vulnerable populations [28]. The data reported to HRSA through UDS is shown in Appendix A

3.5.5 Non-UDS Data

All other information that is not reported to the HRSA is considered non-UDS data. This data is useful for future research, and for better understanding a patient. Since the importance of collecting this data is less, the user interface is designed such that it is much easier to enter UDS data than non-UDS data.

3.6 Search Module

The HEROS system has an elaborate search module that can be accessed from the main form and the administration form. There are a number of cases when homeless patients are unwilling to disclose information to the clinician. Keeping this in mind the search module was created to have a number of search options and filter options. Search can be done by common search strings, like the first name, last name and alias names or a combination of these, in the basic search section. Searches can also be performed based on patient physical description, gender, race and encounter details such as patient seen by, date last seen and location of the encounter. To increase the usability of the application on tablet PCs, most search options can be selected from lists or are check boxes so that the amount of writing required is minimized. After searching for a patient record, it can be opened from the search module for editing, or a new patient file can be created and opened. Users, who have the required privileges, can also delete patient records from the search module.

The search patient module is also used when an unlinked encounter needs to be linked to a particular patient. In this case, the user comes from the unlinked encounter administration module to the search module by clicking on the link encounter button.

Once in the search module, they can link the encounter to a selected patient, or link it to a new patient file, which is then opened for data entry.

3.7 Communication Module

During encounters with patients on the street, we found that most needs of the patient could not be met right away, and required some kind of communication (telephonic or via email) with another clinic, a shelter, or another service outside the scope of HHH. With the possibility of wireless internet flooding in Houston, and a network setup at Palmer Way Station, we setup two methods of communication – Internet telephony using the Skype developer API, and an SMTP mail client for mail transfer.

3.7.1 Internet Telephony

Internet telephony is a category of hardware and software that enables people to use the Internet as the transmission medium for telephone calls. We have used internet telephony, commonly known as Voice Over IP, using APIs developed by Skype [29]. The API is integrated into the GNC module of the application, and is used to make calls directly from the Tablet PC. Contact information can be searched from an extensive contacts list that is available in the database.

3.7.2 SMTP Mail Client

An email client is the other ubiquitous method of communication that we have integrated into the system. This uses the SMTP client support feature that is available in the .NET framework. When an email is composed and sent, the system checks to see if a network connection is present, and sends the email out immediately if it is, else the

email gets queued up in the database and sent when an internet connection exists. This check for an internet connection is done every time the system starts up and shuts down and when an email is sent. All queued emails are sent only during system startup and system shutdown.

3.7.3 Health Level 7 (HL7) support

Health Level Seven is an American National Standards Institute (ANSI) – accredited Standards Developing Organization (SDO) operating in the healthcare arena. Health Level Sevens domain is clinical and administrative data and is a comprehensive framework for the exchange, integration, sharing and retrieval of electronic health information.

The HL7 messaging standard defines how information is packaged and communicated from one party to another. Such standards set the language, structure and data types required for seamless integration from one system to another [30]. HL7 will enable data communication from the HEROS EMR to other HL7 compliant EMRs, especially Centricity, for it being the EMR currently used at Health Care for the Homeless-Houston. HL7 compliance and message passing support is currently being built into the HEROS system.

3.8 Security Implementation

3.8.1 HIPAA Regulations

The Health Insurance Portability and Accountability Act (HIPAA) requires the United States Department of Health and Human Services (HHS) to establish national standards for the security of electronic health care information.

The HIPAA Security Standards must be applied by health plans, health care clearinghouses, and health care providers to all health information that is maintained or transmitted electronically. The standards are intended to protect both the system and the information it contains from unauthorized access and misuse. Each covered entity must assess its systems for potential risk and vulnerabilities to the health information it houses and must develop, implement, and maintain appropriate security measures. The security requirements include:

- Administrative procedures - security measures to protect data and manage the conduct of personnel in protecting data
- Physical safeguards - protection of physical computer systems and related buildings from hazards and intrusion
- Technical security services - processes to protect, control, and monitor information access
- Technical security mechanisms - processes to prevent unauthorized access to data transmitted over a communications network

The HEROS EMR complies by all the security clauses that are mentioned in the final rule published in the Federal Register on February 20, 2003[31] and the HIS security standards checklist [32]. Information security measures that have been implemented in the system are Biometric Security, Secondary login, and auto logout. A user needs to login into the system first with a fingerprint reader followed by a user name and password. If the system remains inactive for five minutes, it will

automatically log the user out of the system. This is a basic security requirement by HIPAA.

The system has role based login which can be administered from the admin module of the program. Different roles (Program Administrator, Clinician, and Case Manager) have different levels of access to the system.

3.9 Dynamic Diagnosis List

Every encounter with a patient is recorded in the visit tab of the application and diagnoses for an encounter are recorded in the Visit – Diagnoses section. The Center for Disease Control and prevention and the National Center for Health Statistics (both a part of the Department of Health and Human Services) have compiled a database of diseases and injuries and have associated each entry with a code known as the ICD9 code. Any diagnosis for an encounter must be taken from this database. This database has over 30,000 entries and searching through it can become tedious and inefficient. To solve this problem, the system has two search features; one is a top 20 diagnosis list, and the second is a diagnosis categorization and search module. The top 20 diagnosis list is a dynamically changing list of the most frequently accessed diagnosis. On most encounters the diagnosis will be present on this list. If the diagnosis cannot be found on the frequent diagnosis list, then the clinician can use the diagnoses categorization and search module. Here, every diagnosis has a category and a sub-category that they belong to, and a step-by-step filtration can be performed to obtain the final diagnosis. The search module also has a text-comparison feature which can be used to filter the

final diagnosis list based on the search string entered. The final list is filtered for every letter entered, making the search more dynamic in nature.

3.10 Uniform Data System (UDS) Report Generator

The UDS report generator is programmed using Crystal Reports for Visual Studio .NET and can be accessed through the administration module of HEROS. Patient records, seen between two given dates, that have all UDS data fields complete, are generated in the report. This UDS report is used for reporting patient information to Health Resource and Service Administration (HRSA). The data fields that are reported is shown in Appendix A

3.11 System Administration

The HEROS system is data driven, and dynamic in nature, requiring a complex system administration module. Expandability and flexibility of the system for expansion to other sites also add to the need of a detailed administration module. The administration module is accessible from the main application by clicking on the Admin Module button. Access to the administration module is based on user privileges, and only system administrators have access rights to this module.

The administration module is divided into four categories, as shown in the system architecture diagram in Figure 3.3

3.11.1 GNC Administration

The GNC administration module is used to manage all functionality and data associated with Goal Negotiated Care. It consists of the following sub-categories:

3.11.1.1 GNC Meta Data

The GNC Meta Data section is used to control all meta data that is used in the GNC section. This includes inserting, deleting, and editing fields such as list of 'Goals', list of 'Sub-goals', list of 'Who', list of 'Why', types of 'Transportation', list of 'Patient tasks', list of 'Clinician tasks' etc. Additional description can be added for all fields which are used as hints to the clinician in the application.

3.11.1.2 Contacts

The Contacts section is used for inserting, editing, and deleting contact information. This information consists of contact details and the person's association with a particular clinical location. It also contains a description field which is used as a tool tip in the GNC module. The contact information is primarily used in the communication module.

3.11.1.3 Clinic Mapping and Details

The clinic mapping and details section is used for associating clinic groups, subgroups and clinic names together. This section is also used for managing clinic specific information like, gold card requirement at a particular clinic, transportation facility at a particular clinic location, etc.

3.11.1.4 Goals and Task Mapping

The Goals and Task Mapping section of GNC administration is the heart of GNC administration module. All associations for GNC are made here. For example goals are mapped to sub-goals and patient, clinician, and miscellaneous tasks are associated to a goal. Advanced administration features, such as date or day dependence

of a particular task can also be set here. Having such a configurable administration module for GNC enables the application to be easily ported to another site. A screen shot of the GNC administration module with the Goals and Task Mapping section expanded is shown in Figure 20 of Appendix B.

3.11.2 User Information Administration

The User Information Administration is used to manage user access into the system and maintain user information and roles. Only users with administrative privileges can access this section of the system administration module. Functions in this section include editing user information, deleting user information and inserting new users. A screen shot of the User Information Administration is shown in Figure 22 of Appendix B.

3.11.3 Clinical Information Administration

The Clinical Information Administration section is used for managing all meta-data associated with the clinical and demographic section of the system. All data that is not associated with GNC falls under this section. Information can be edited, deleted, added and the order in which grouped information is visible can be changed. A screenshot of the Clinical Information Administration section is shown in Figure 19 of Appendix B.

3.11.4 Unlinked Encounter Administration

The Unlinked Encounter Administration section is used for listing and managing unlinked encounters. The system normally displays the five most recent unlinked encounters. To access remaining encounters, the user must come to this section. Here

encounters can be viewed, deleted and set as an orphan encounter. An encounter set to be deleted will be removed completely from the system. An encounter set as an orphan encounter is marked as not viewable but still exists in the database for statistical purpose. A screen shot of the Unlinked Encounter Administration section is shown in Figure 17 of Appendix B.

CHAPTER 4

CASE STUDY

The pre-GNC HEROS EMR system was alpha and beta tested at Healthcare for the Homeless-Houston (HHH), Houston, TX in September 2006. After feedback from the clinician users, more changes were made to the system and a final release version was launched at HHH in December 2006.

Currently, a beta version of the complete EMR including GNC is being tested at HHH and a release version is expected to be launched in May 2007. To validate our system, we have done a case study to compare data collection on paper to the one using of the HEROS EMR. We have also compared the GNC healthcare model to the traditional healthcare model.

4.1 Case Study Design

4.1.1 Case Study Goal

For our case study, we concentrated our research on the following two goals.

1. Compare paper based data collection on the street to use of the HEROS EMR
2. Compare the traditional healthcare model to the GNC healthcare model

The case study comprised of using the HEROS system during outreach programs to collect health data from the homeless. Clinicians who used the system were surveyed to obtain their feedback on the new Goal Negotiated Care workflow and the

implementation of this workflow in the HEROS system. Their feedback on the use of an EMR during medical outreach was also studied.

4.1.2 Case Study Population

The case study was done at Healthcare for the Homeless-Houston, and the population consisted of homeless patients seen on the street by HHH. These patients were encountered on the street, in encampments, under bridges, at day shelters and at outdoor soup kitchens. A total of 1108 patients were seen by 6 clinicians and 4 case managers.

4.2 Case Study Results

We obtained a number of interesting results from our case study. A total of 3594 patient encounters were recorded for the 1108 patients seen. This comes to an average of 3.2 encounters per patient, which means that on average a patient came back at least twice after having an initial encounter with a clinician. This is almost a three times increase to the 1.2 encounter per patient calculated at HHH prior to the use of HEROS. This calculation is based on all patients seen by HHH during MSO and where paper records were used to record an encounter using the traditional healthcare model.

A total of 3048 goals were recorded and content analysis of the goals revealed four major themes: Pre-healthcare, Engagement, Healthcare, and Social Services. A more detailed breakdown of the recorded goals shown in the Table 4.1 subcategorizes each of each of the four major themes that we identified. Against it we see negotiated goals for each of the subcategories, which show a positive engagement with the patient

towards goal formulation, and attained goals – which depict successfully attained goals by the patient.

Table 4.1 Content Analysis of Goals

Goal Categories	Negotiated Goals	Attained Goals
Pre-Health Care		
Birth Certificate	6	1
Picture Identification	96	15
Indigent Insurance Card	184	29
Category Total	286 (13%)	45 (8%)
Engagement		
Health-care Appointment	868	228
Follow-up Appointment	292	111
Category Total	1,160 (52%)	339 (57%)
Health Care		
Obtain Prescriptions	158	60
Diagnostic Tests	89	27
Medical Treatment	173	42
Substance Abuse Treatment	81	14
Mental Health Treatment	49	11
Category Total	550 (25%)	154 (26%)
Social Services		
Obtain Housing	34	3
Get Education/Develop Skills	39	9
Transportation	45	19
Case Management	59	11
Employment	14	2
General (e.g., Food Stamps)	38	11
Category Total	229 (10%)	55 (9%)
Grand Total	2,225	593

These recorded goals enabled us to further refine the workflow of GNC and categorize goals in a more organized manner. We also noticed that the initial training required to use HEROS was much less than other traditional EMRs in the market. HHH performs a 4 week training for their staff to use Centricity by GE, where as HEROS required just one day orientation and one week training following it.

We were also able to obtain a large amount of statistical information regarding the homeless, such as ethnicity ratio, most common diagnoses, etc which is very important for future work and medical studies.

4.3 Clinician Feedback on using HEROS

We were able to get substantial amount of feedback from the clinician and users of HEROS. All users felt that there was an increase in patient engagement which is evident from the overall number of encounters and the significant increase in the number of encounters per patient. Users felt that with GNC they were able to focus on building relationships rather than just give medical treatment and they were able to address both the medical and the basic needs of the patient. The clinicians were also impressed by the ease of use of the application and the flexibility with TPC use in street outreach, compared to Centricity that is installed at the inpatient clinic at HHH.

4.4 Patient Feedback on the use of HEROS

There was positive attitude in the homeless towards the use of technology for them and a 93% acceptance rate that was calculated based on informal discussions that we undertook with 326 patients willing to engage in conversation at the Palmer Way Station, Houston, during medical outreach and field tests. Patients were nonplussed and flattered by the use of high-tech methods for them.

CHAPTER 5

RELATED WORK

A substantial amount of work has been done in the field of medical informatics and EMR design, and about 250 different EMRs are currently available in the market. Most of these EMRs run on complex client server architecture and require a connected environment. Some of the major ones are Centricity by General Electric [33], TouchWorks and HealthMatics by Allscripts Healthcare Solution [34], Bond Clinician by Bond Technologies [35] and eClinicalWorks by eClinicalWorks [36]. These EMRs are heavy weight applications which follow the traditional healthcare model and are well suited to large organizations and clinics.

eClinicalWorks 7.0 has three categories namely EMR, Practice Management and Patient Portal. The EMR is the heart of the system which has features that streamline the patient visit and simplify the documentation process. New features that are a part of the EMR are ePrescribing – electronic prescription request submission to an enrolled pharmacy, conversion of patient records into different formats like .pdf etc. The Practice Management section has features such as resource scheduling, financial reports generation and eligibility check. The patient portal section makes communication with patients easier and allows patients to view their diagnostic results, lab results and appointment information. Clinicians can also communicate with the patent from here.

Allscripts has two versions of their EMR: HealthMatics - for organizations with less than 25 physicians and TouchWorks – for organizations with more than 25 physicians. Both these EMRs have features similar to those present in eClinicalWorks and has a based Web-based architecture.

All these systems are excellent for hospital and inpatient use, but cannot be used for street outreach.

To the best of our knowledge, there were no EMRs available for street outreach until HEROS was developed. Two programs in the country, one in Boston, MA and the other in Pittsburgh, PA use handhelds for there MSO program, but neither of them use a specific program or workflow on the handhelds. HEROS is the first EMR in the country to be specially designed for street outreach and implementing the GNC model for healthcare.

The Table 5.1 shows a high level comparison of GE's Centricity and the HEROS EMR.

Table 5.1 Comparison of Centricity and the HEROS EMR.

HEROS	**Centricity**
Light weight application	Heavy weight application
Follows GNC work flow model	Follows traditional care model
Runs on tablet PCs	Runs on desktop client machines
Works in a disconnected environment	Works in a connected environment
Cheap	Very expensive ($200000)
Easily portable (both hardware and software)	Not easily portable
Patient driven	Clinician driven
Less functionality	More functionality

CHAPTER 6

CONCLUSIONS AND FUTURE WORK

6.1 Conclusions

This thesis introduces homelessness and its scope in the United States, and Medical Street Outreach (MSO) programs that try to meet the needs of the homeless. We describe traditional healthcare model and the reason why it cannot be used in street outreach for the homeless. We introduce the Goal Negotiated Care (GNC) healthcare model and explain its workflow and benefits to the homeless as compared to the traditional healthcare model and further discuss the design, implementation and analysis of Homeless Electronic Medical Record System (HEROS), an Electronic Medical Record System that works on the GNC healthcare model.

The main contribution of my work is proposing GNC as a healthcare model for street outreach, designing and implementing an EMR based on GNC and validating the product at Healthcare for the Homeless-Houston.

A case study was undertaken to compare paper based records to the HEROS EMR and also to compare the traditional medical healthcare model to the GNC healthcare model. From the results of the case study we found the HEROS EMR to be more efficient on the street and an increase in patient encounter after using the GNC model of healthcare.

6.2 Future Work

Our work has made a significant contribution in healthcare models and in Electronic Medical Records that are used specifically for street outreach. We have been awarded silver partner status with Motion Computing through HHH based on our EMR design. We have obtained significant interests in our product, from 20 other organizations across the globe, who want to implement the HEROS system as part of their medical outreach programs. We are currently working on product orientation and product customization for these sites. The following are some of the future enhancements for the HEROS EMR.

- Support for new hardware. There are a number of new tablet PCs being manufactured by different vendors that are specially designed for the medical field. One such product is the C5 by Motion Computing [37], which has advanced features like an RFID tag reader, barcode scanner and a high resolution digital camera built in. We would like HEROS to support such devices and features.
- Convert to a service oriented architecture. Having received so much interest in the product from other organizations, we would like to consider changing HEROS to service oriented architecture in future.
- HL7 Support. We would like to make the HEROS EMR fully HL7 compliant and enable it to interact with not just Centricity, but any other EMR that is HL7 compliant.

The GNC healthcare delivery model is not confined to just the homeless, but can also be applied to other patient populations. We would like to apply the idea and expand

the product to all patient populations. This model, with few or no changes, can also be applied in emergency relief situations.

APPENDIX A

UNIFORM DATA SYSTEM (UDS) REPORTING DATA FIELDS

Uniform Data System (UDS) reporting data fields

Patient Last Name
Patient First Name
Date of Service
Location Encountered
Gender
Race
Date of Birth
Last Slept
Family Type
Number of family members
Income
Social Security Number
Insurance Details
Patient Diagnoses

APPENDIX B

SNAPSHOTS OF THE SYSTEM

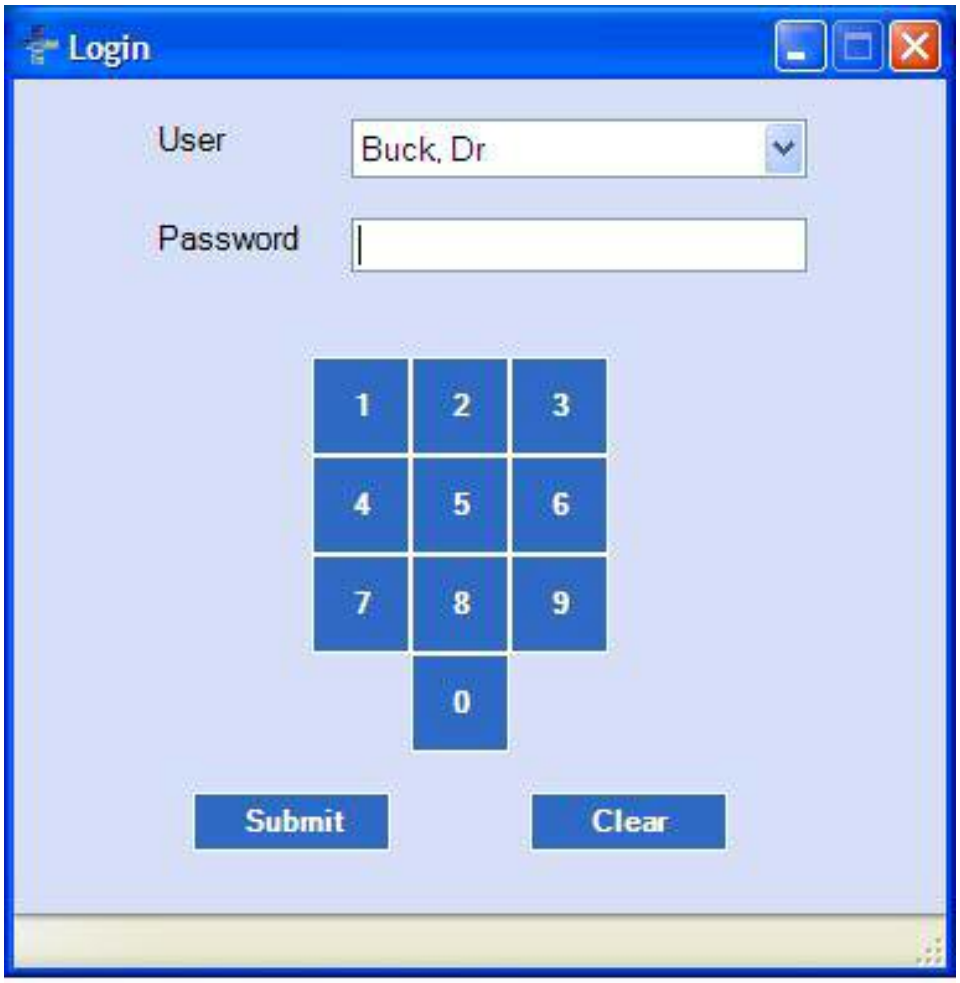

Figure 1 Login to HEROS

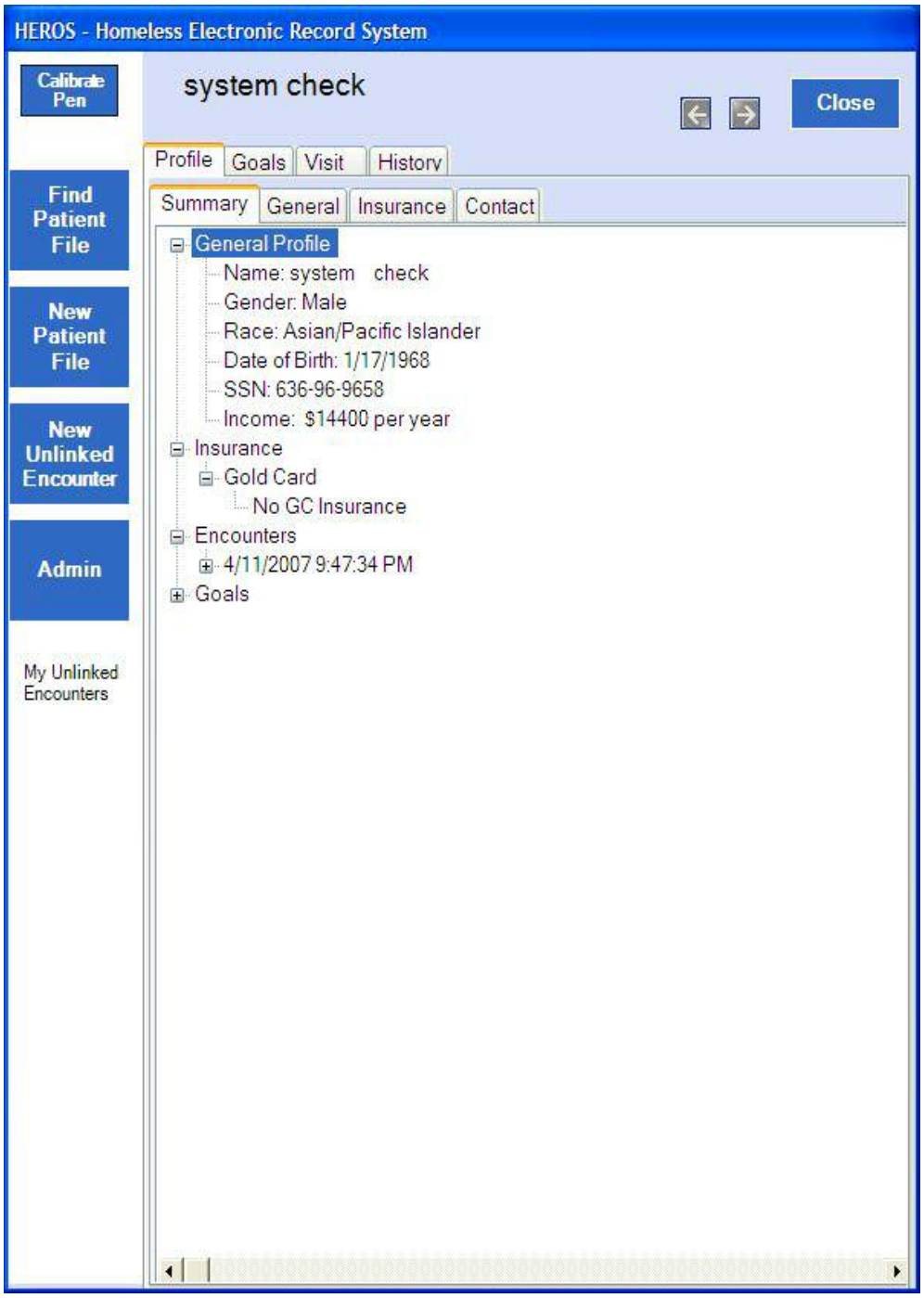

Figure 2 Patient Summary

Figure 3 Patient General Information

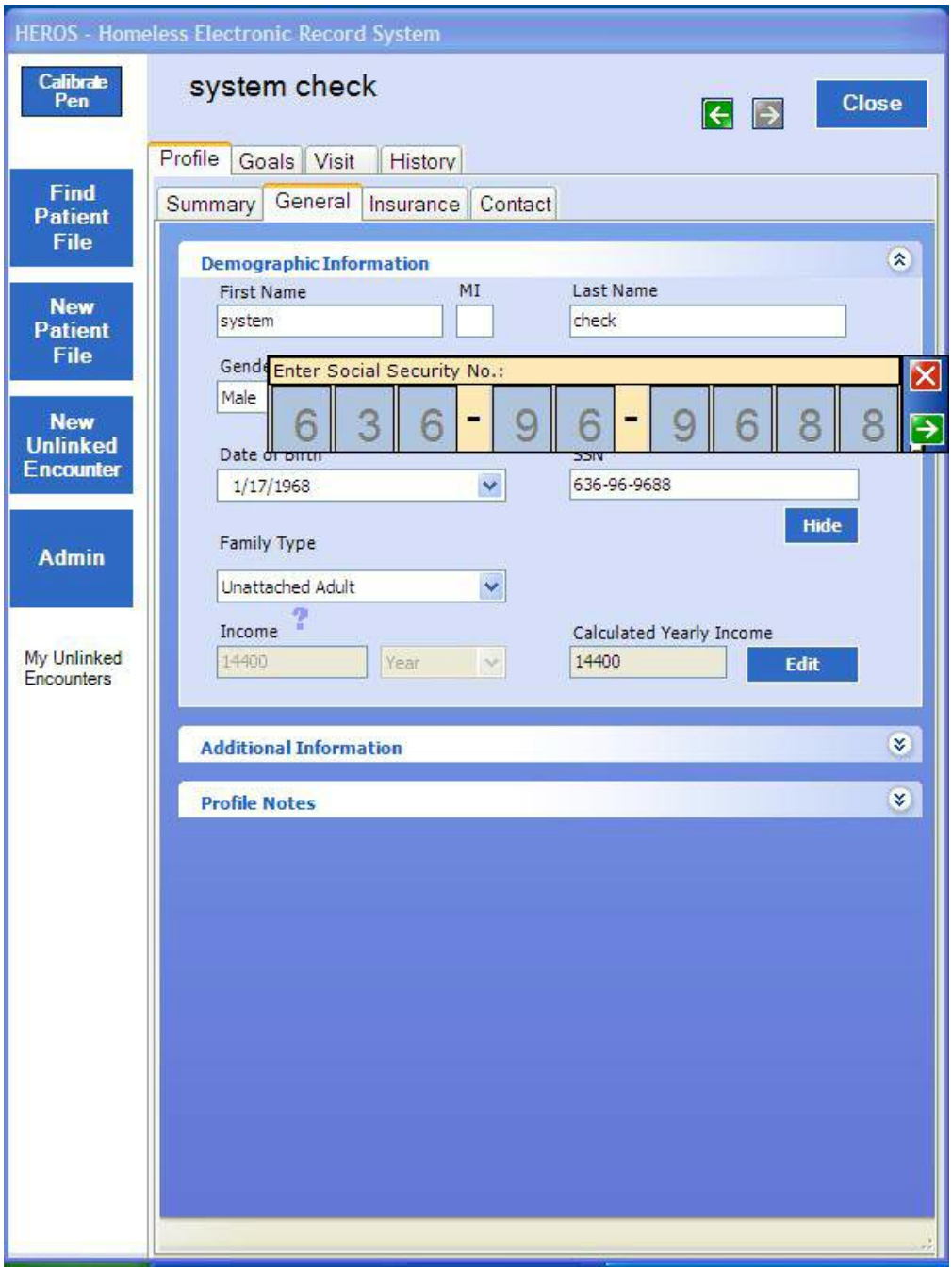

Figure 4 Number Recognition Feature

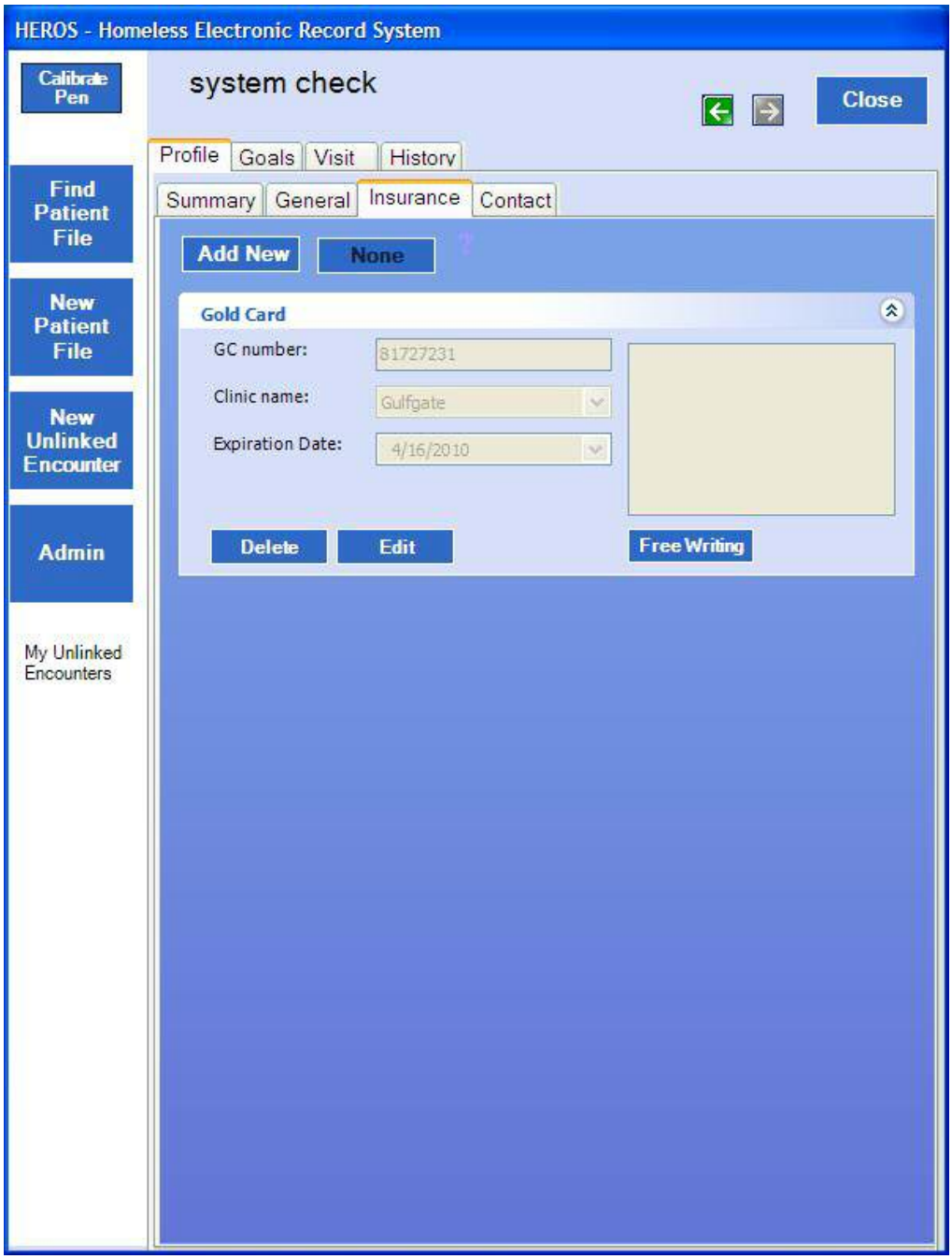

Figure 5 Patient Insurance Information

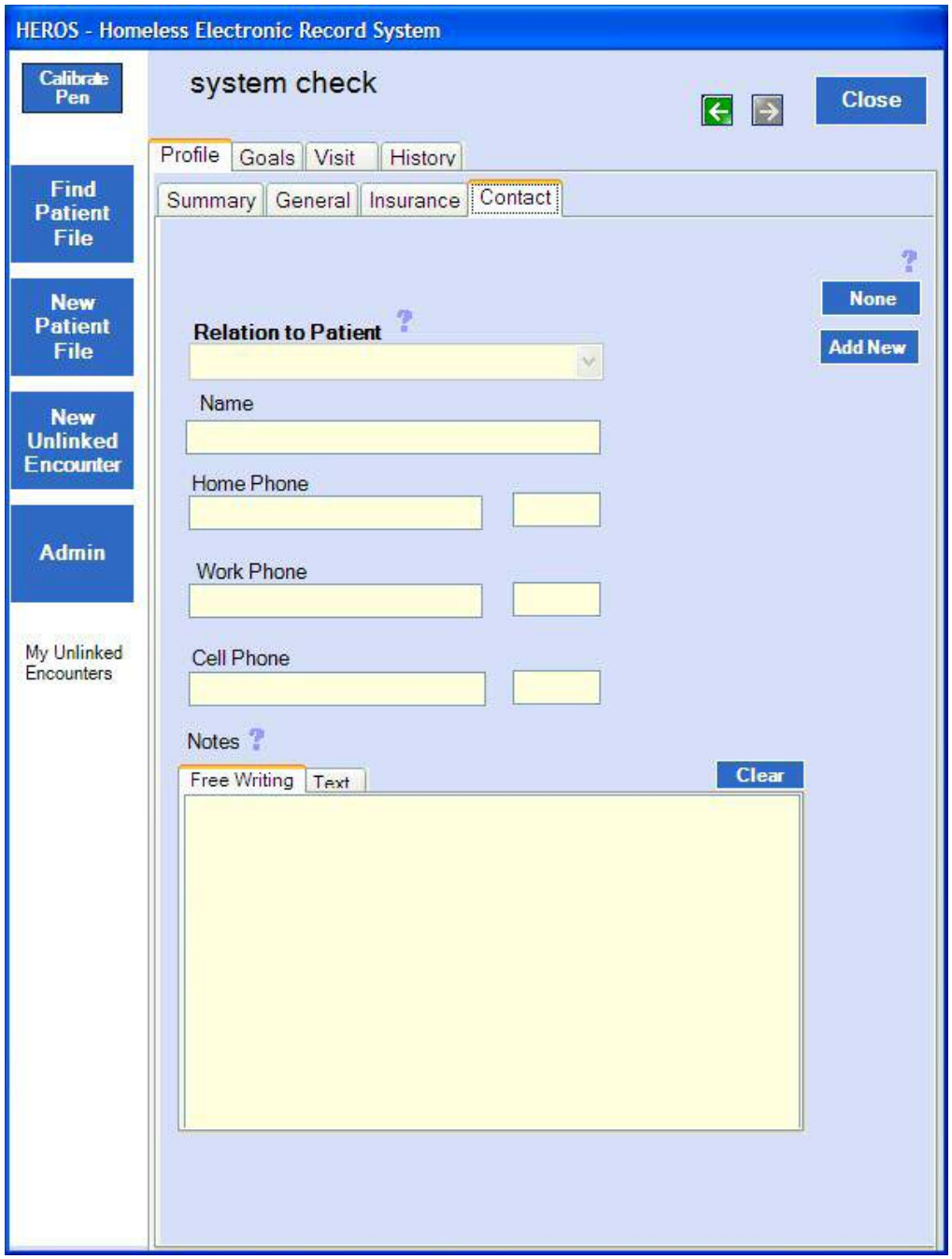

Figure 6 Patient Contact Information

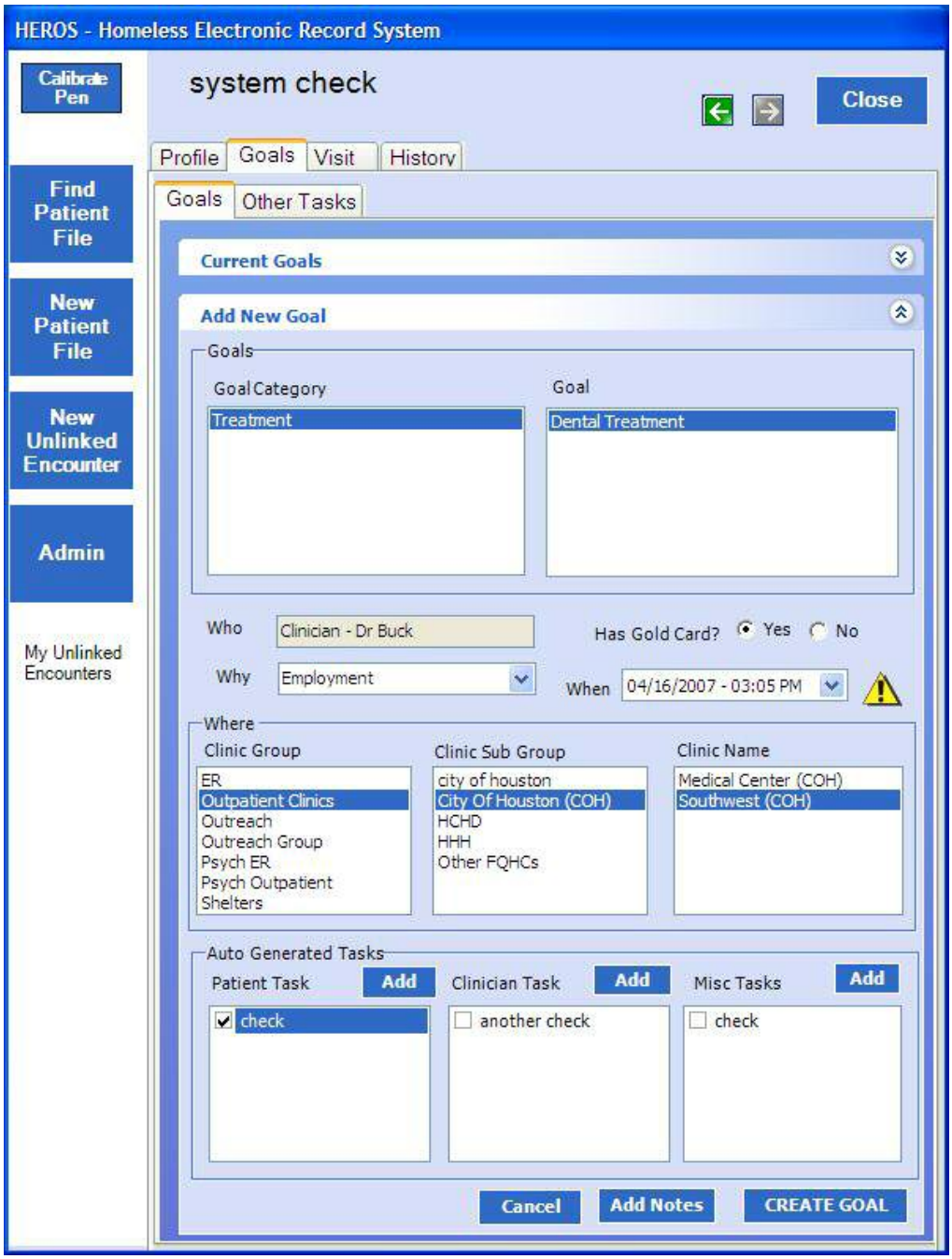

Figure 7 Add New Goal

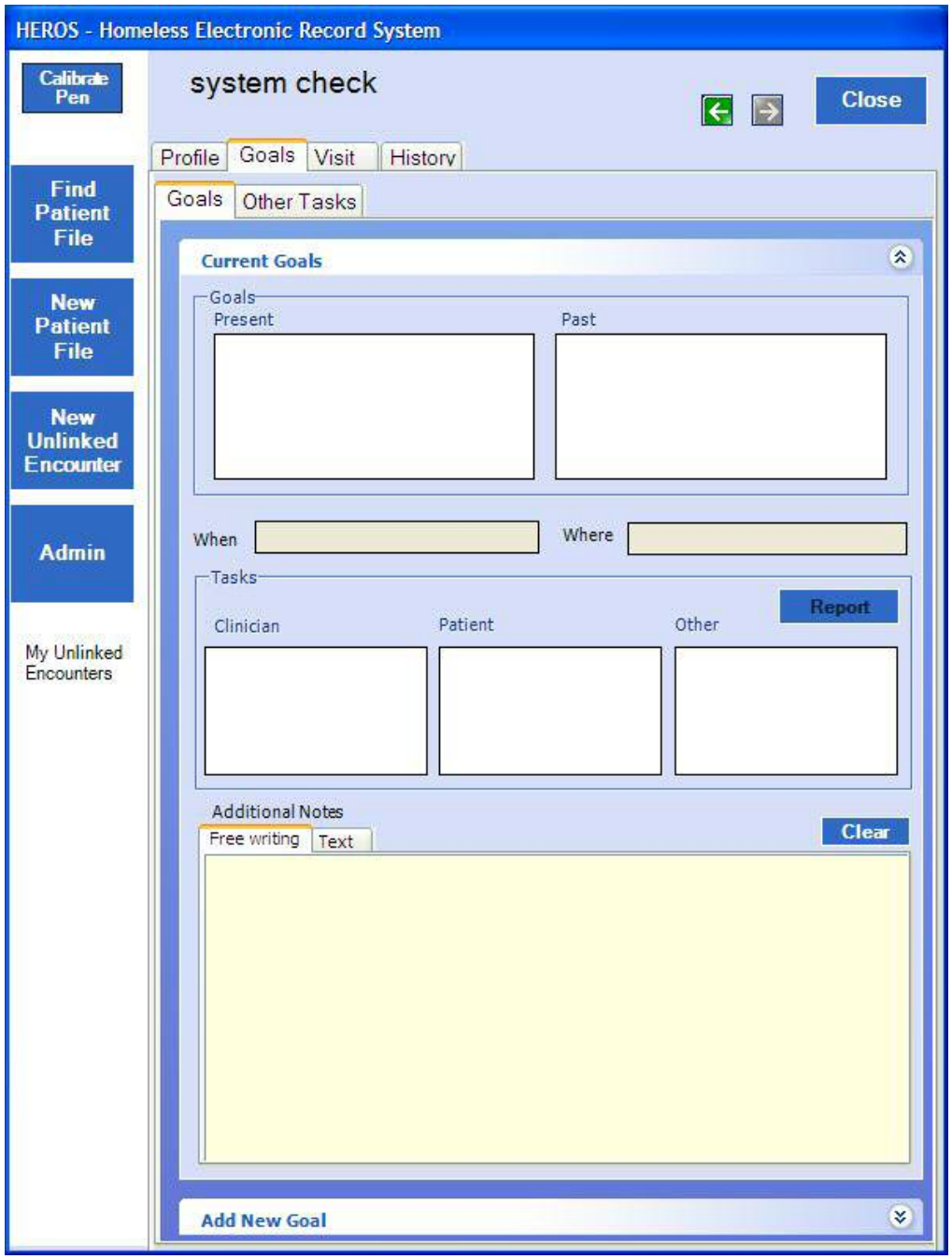

Figure 8 Patient's Current Goals

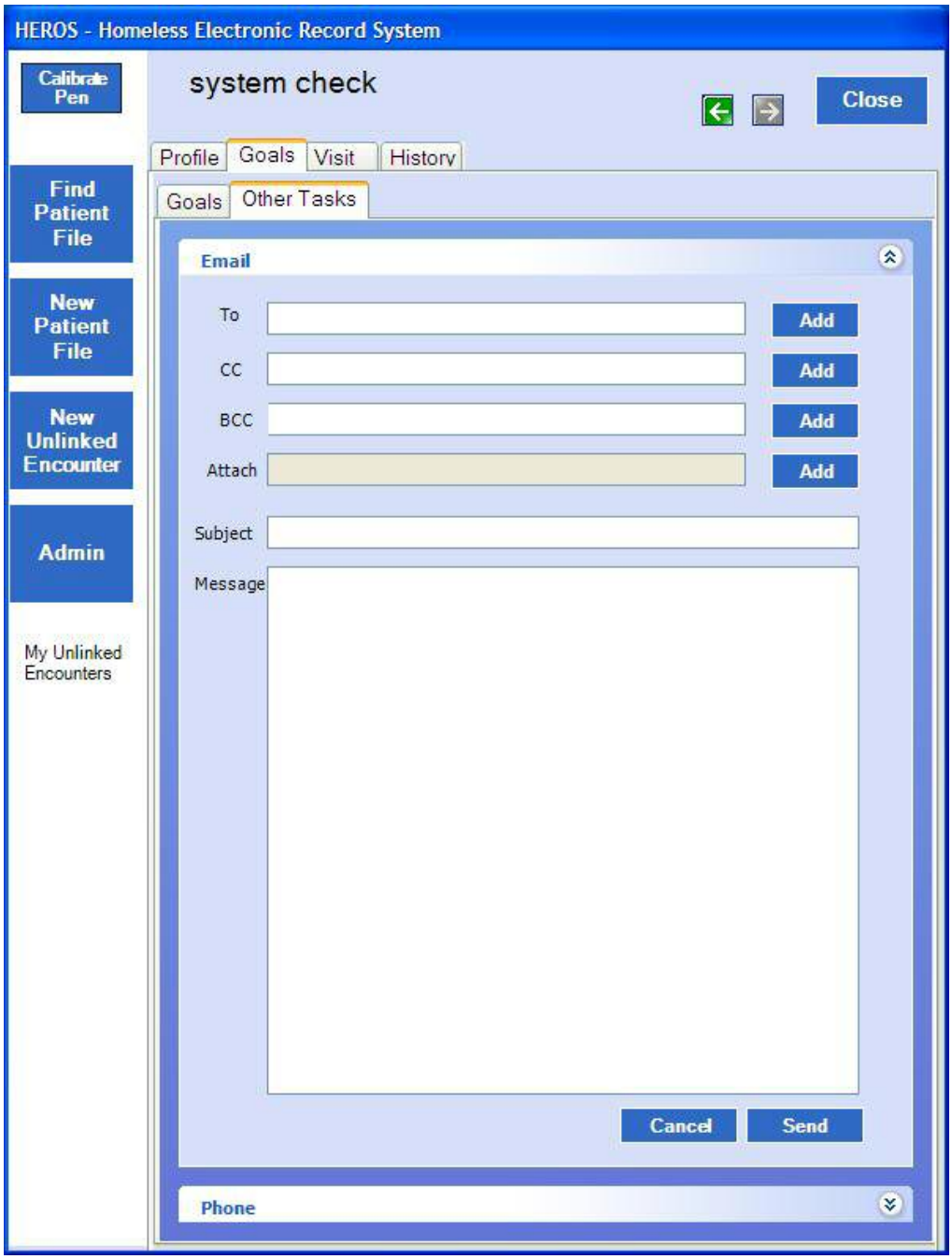

Figure 9 Communication Module

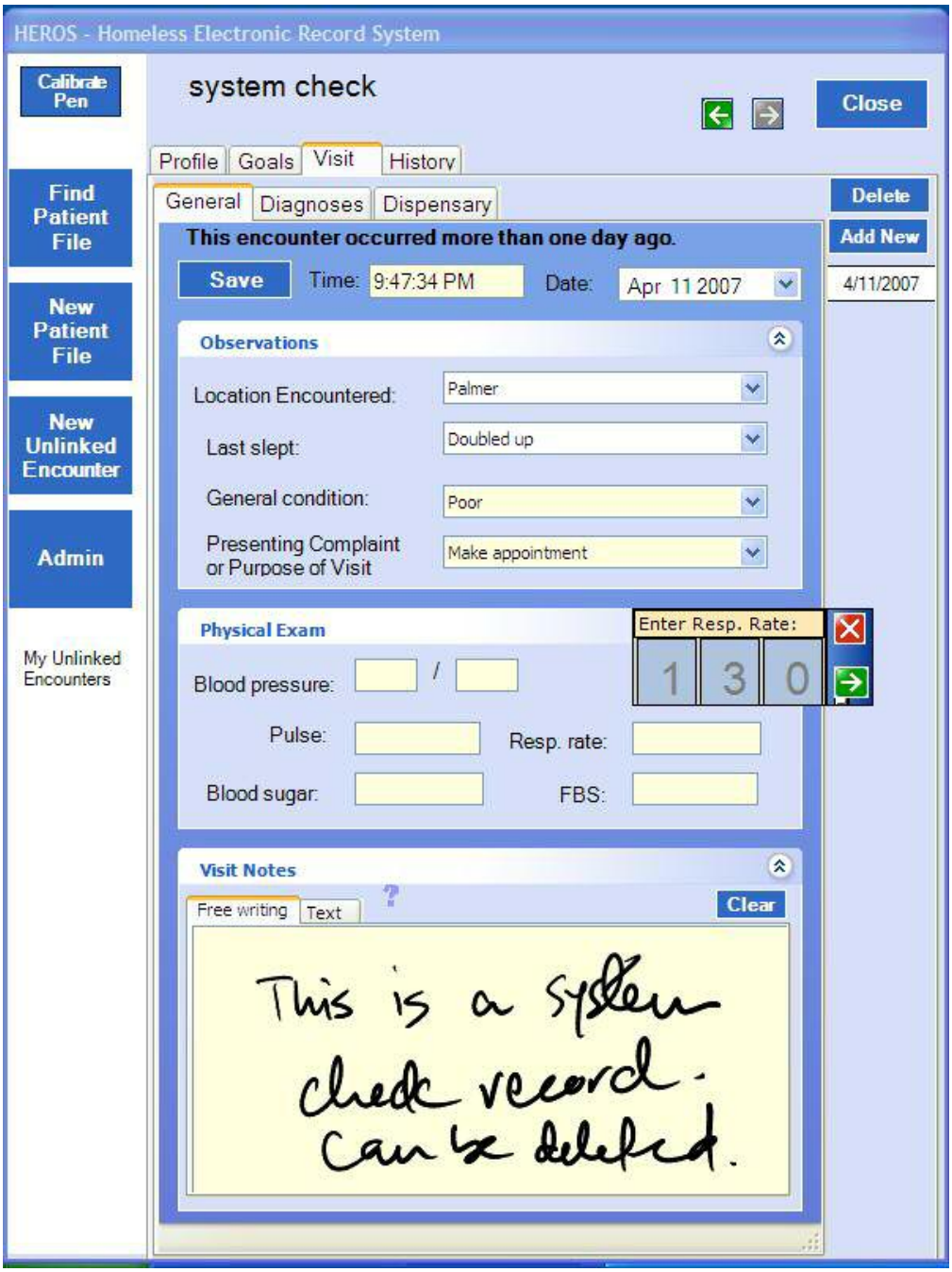

Figure 10 General Information about a Visit

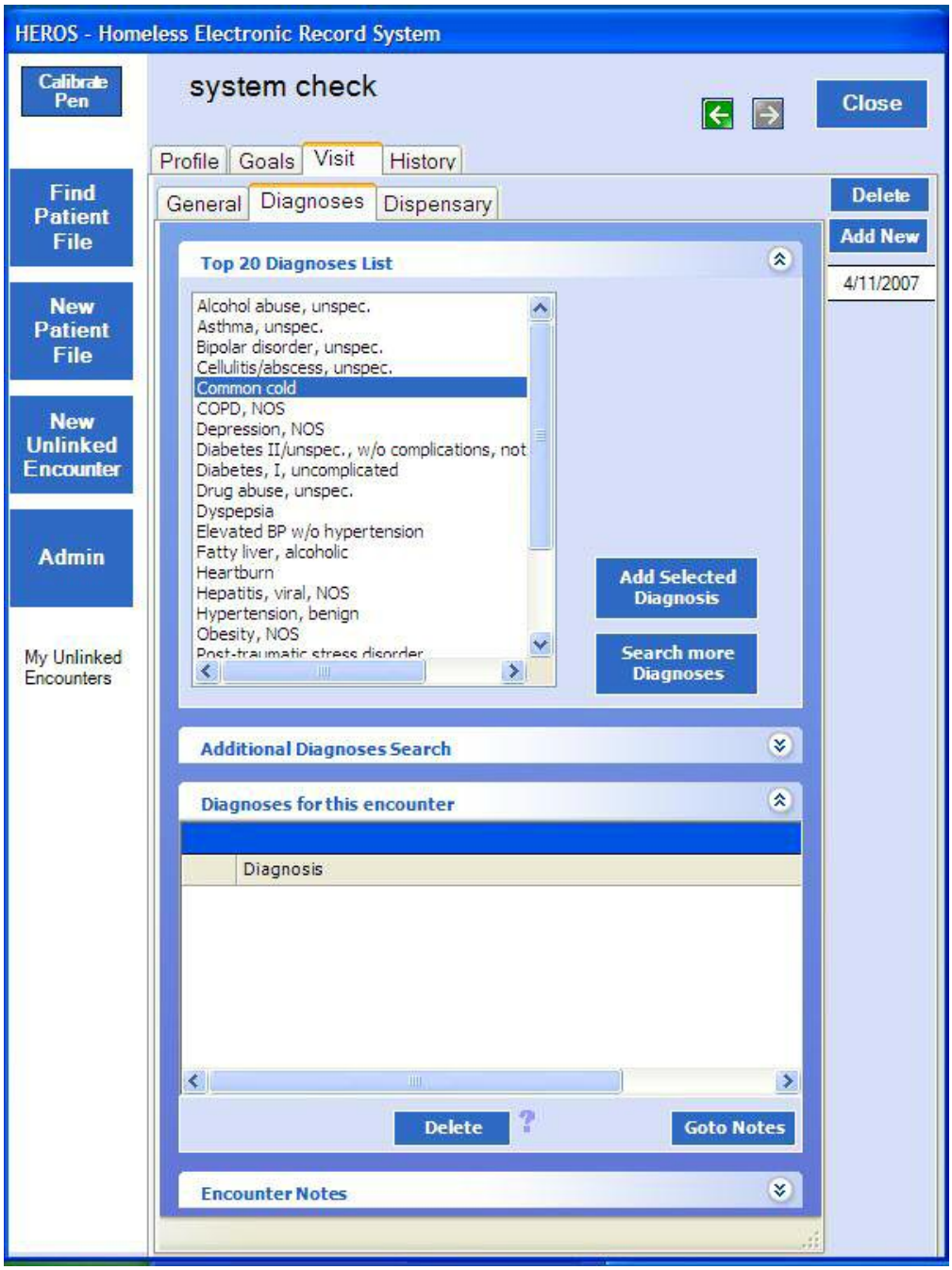

Figure 11 Top 20 Diagnosis List

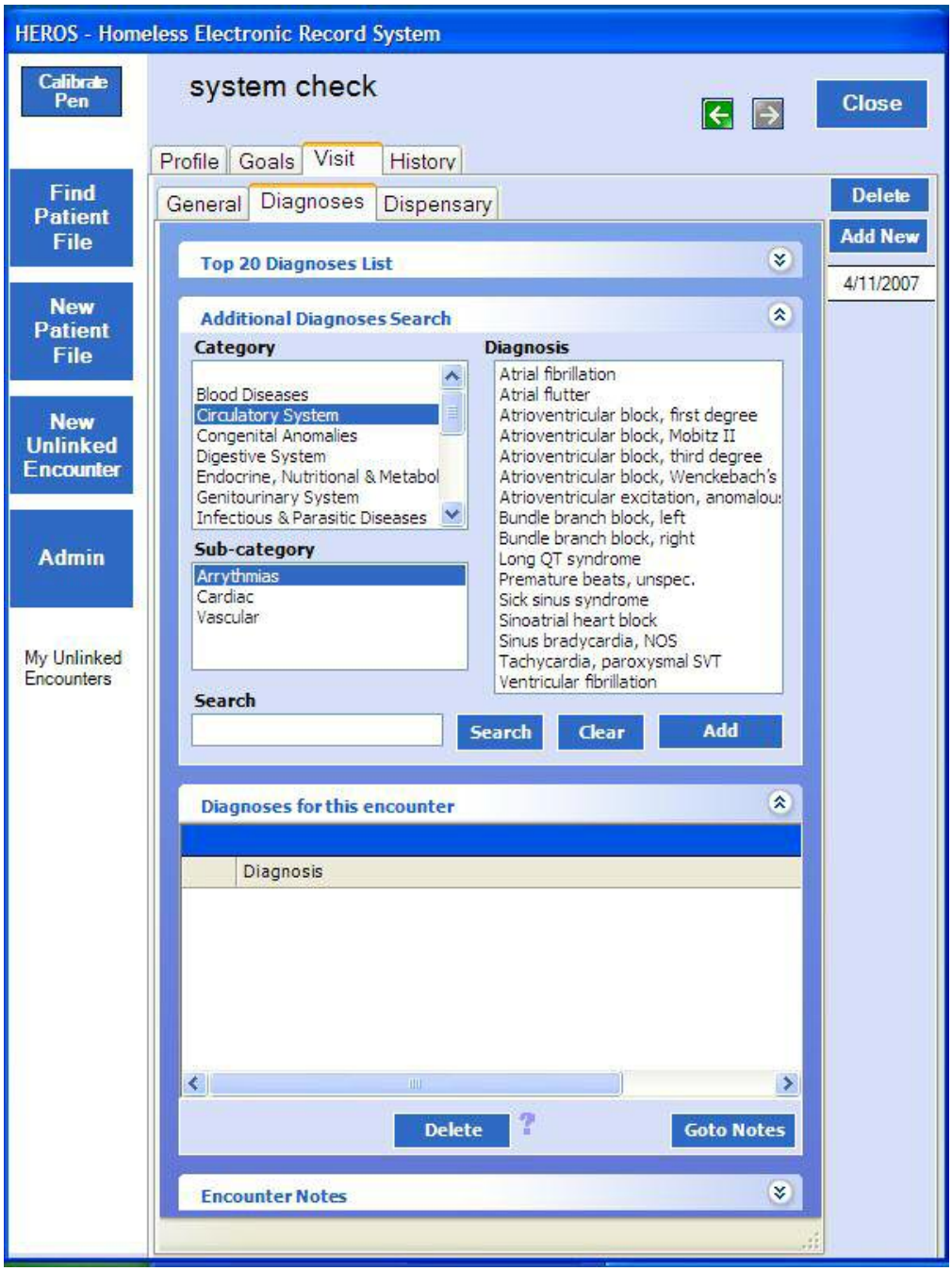

Figure 12 Search Diagnosis

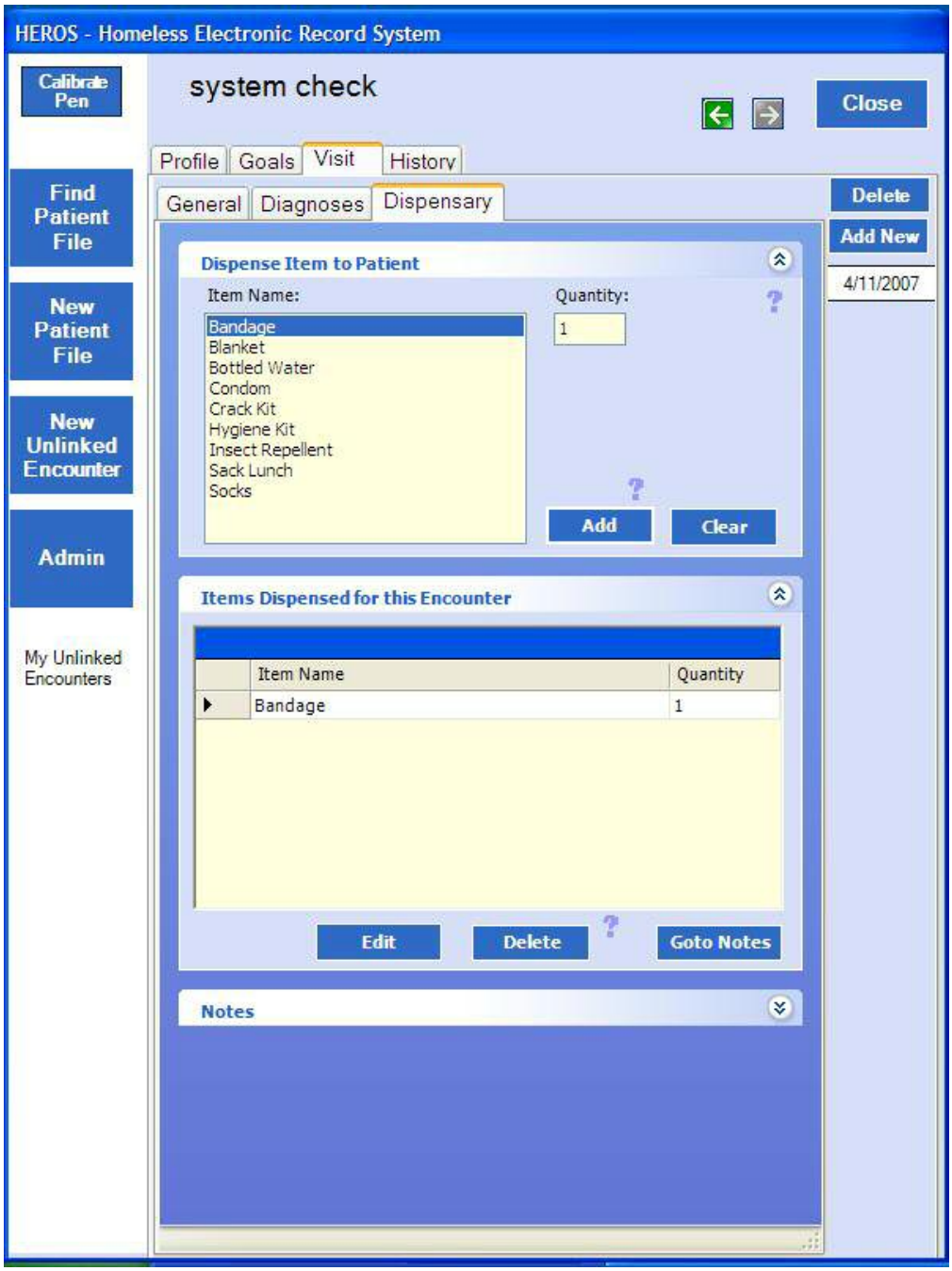

Figure 13 Patient Dispensary Details

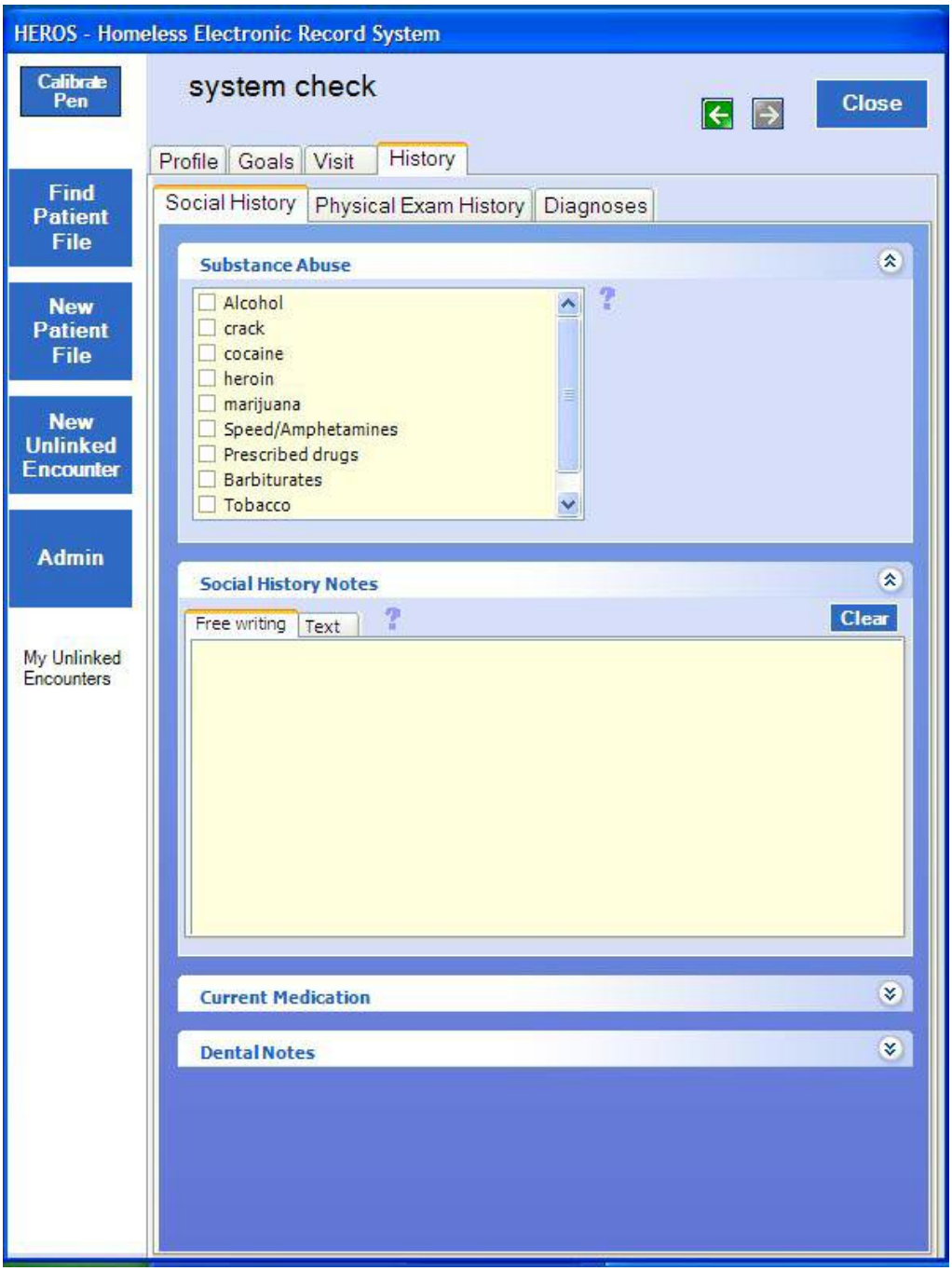

Figure 14 Patient Social History

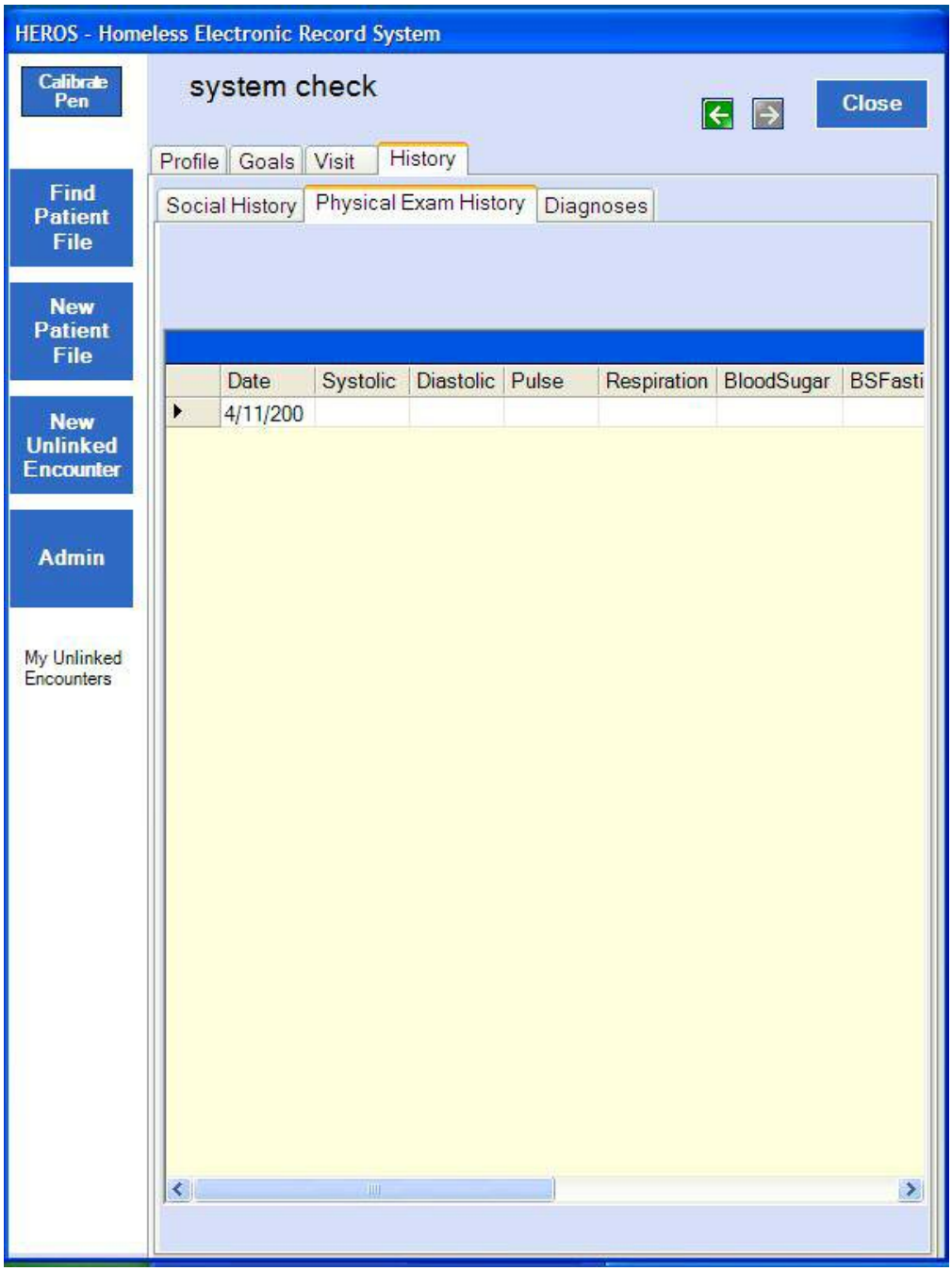

Figure 15 Physical Examination History

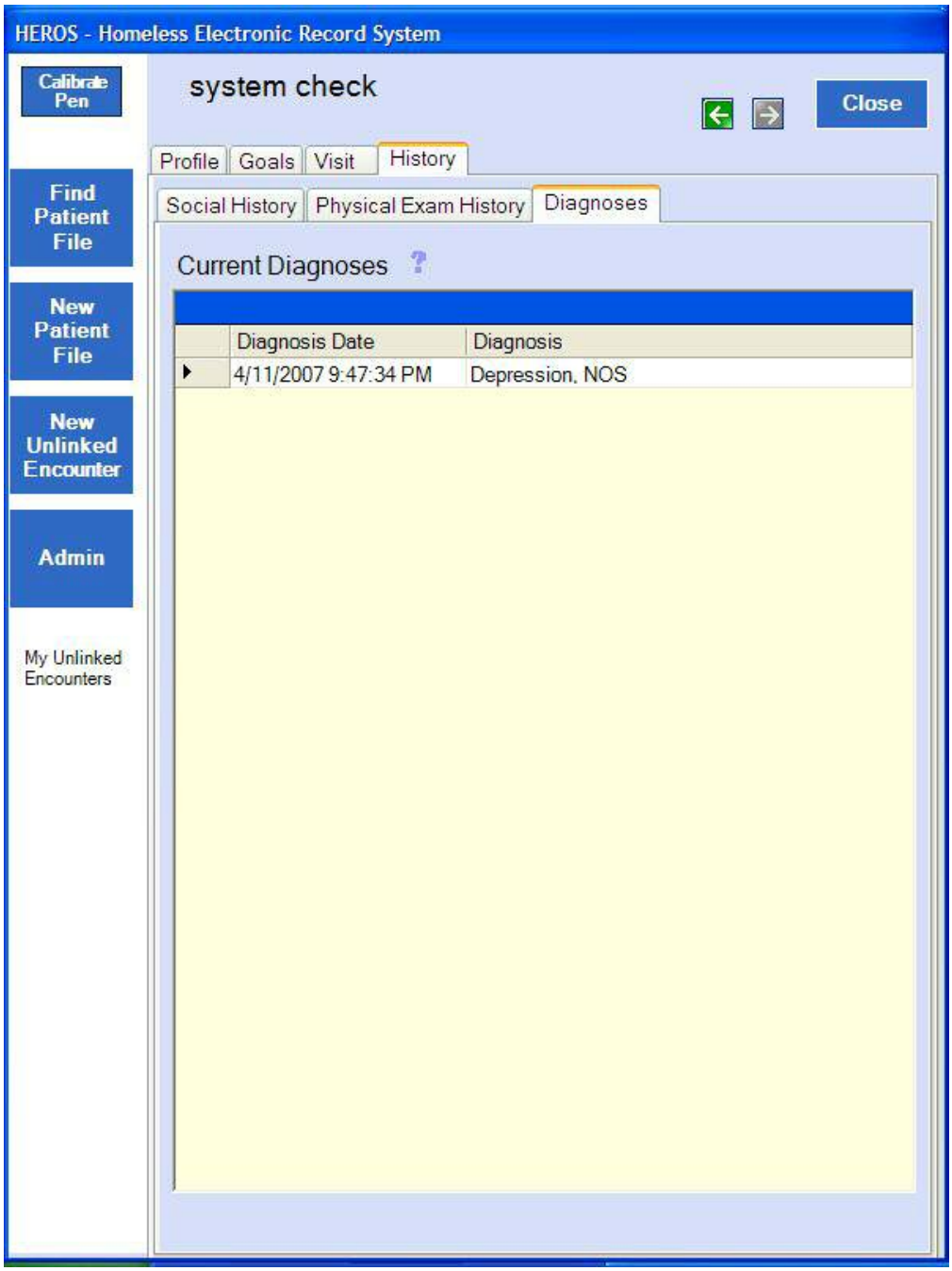

Figure 16 Patient Diagnoses History

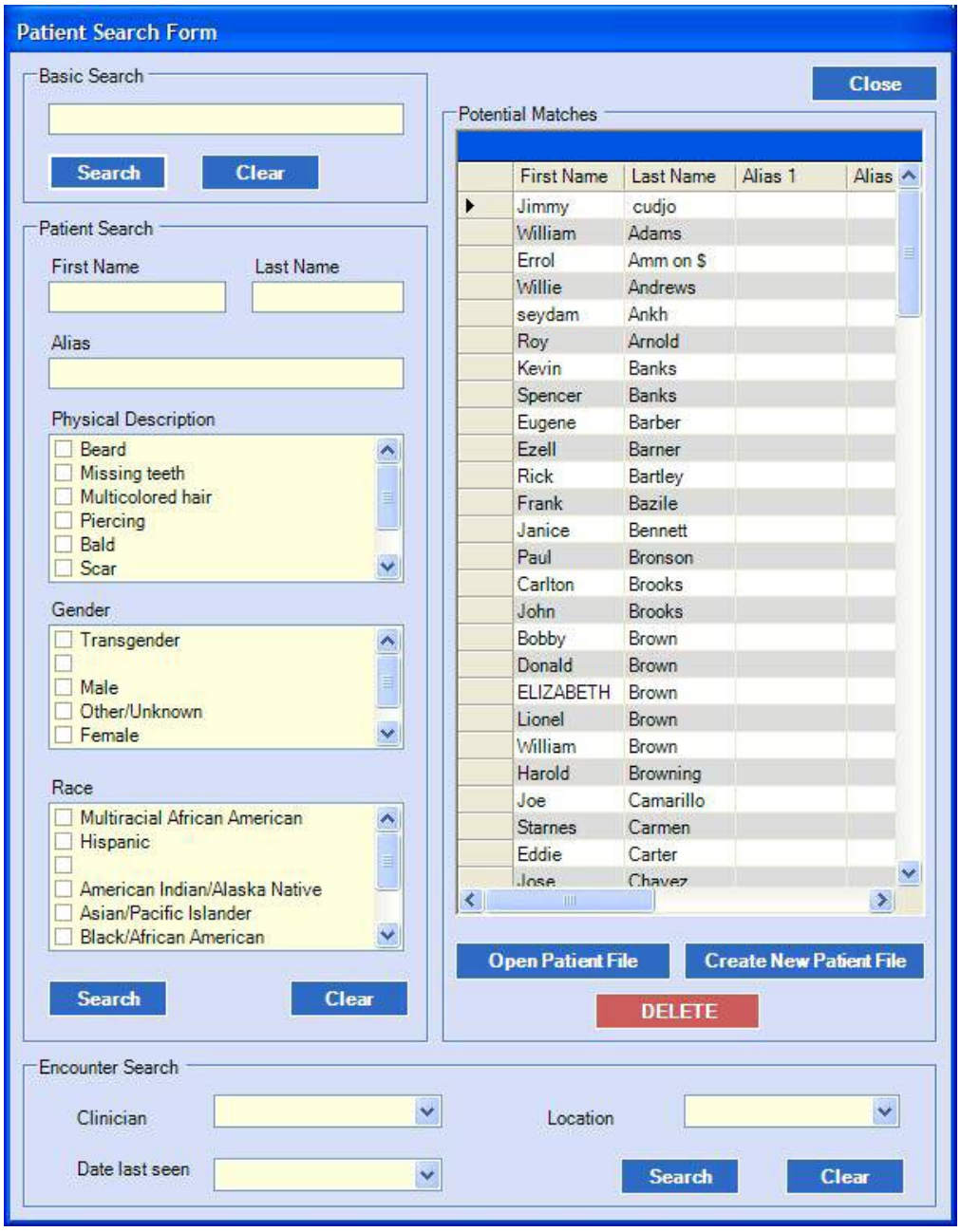

Figure 17 Patient Search Module

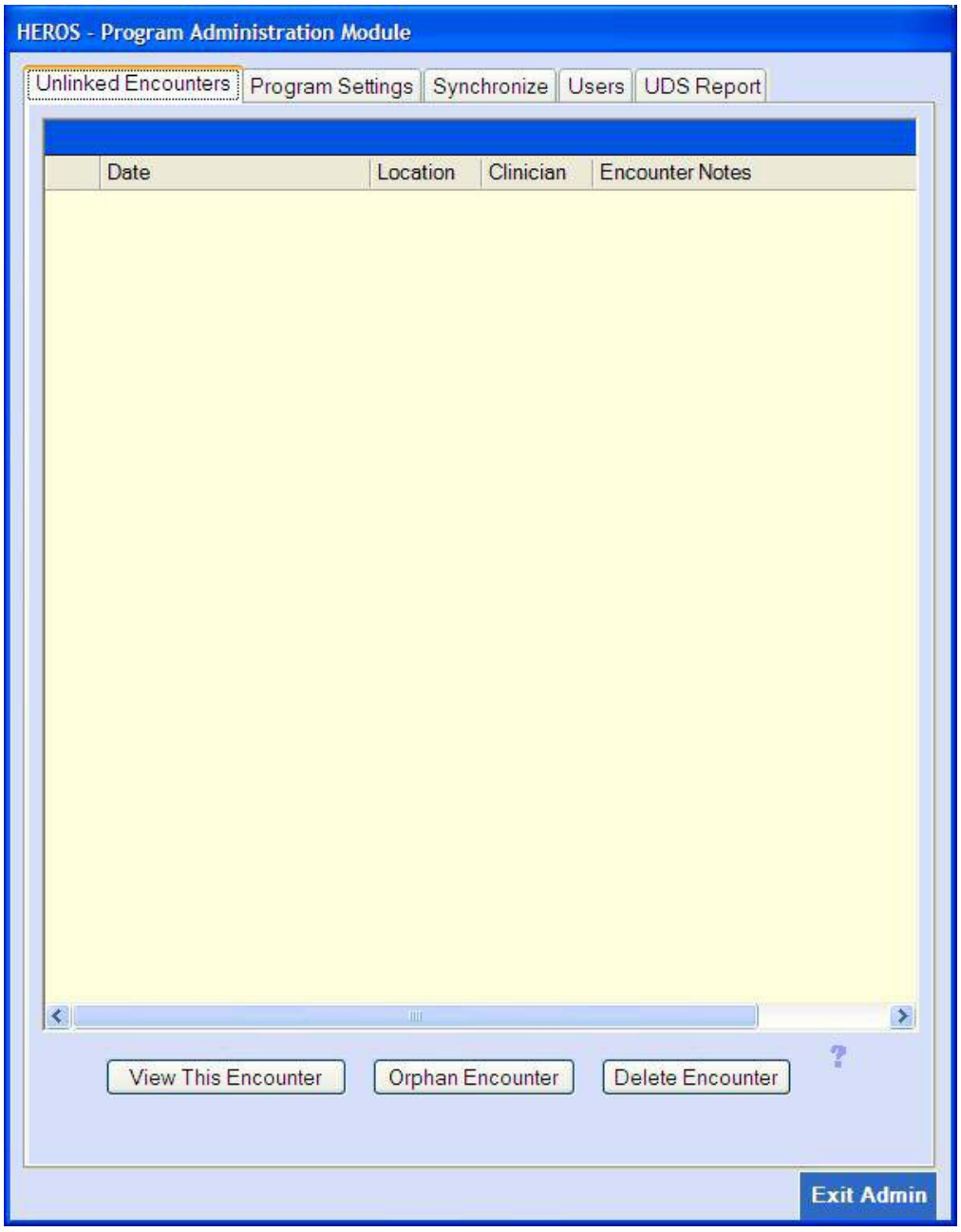

Figure 18 Administration of Unlinked Encounters

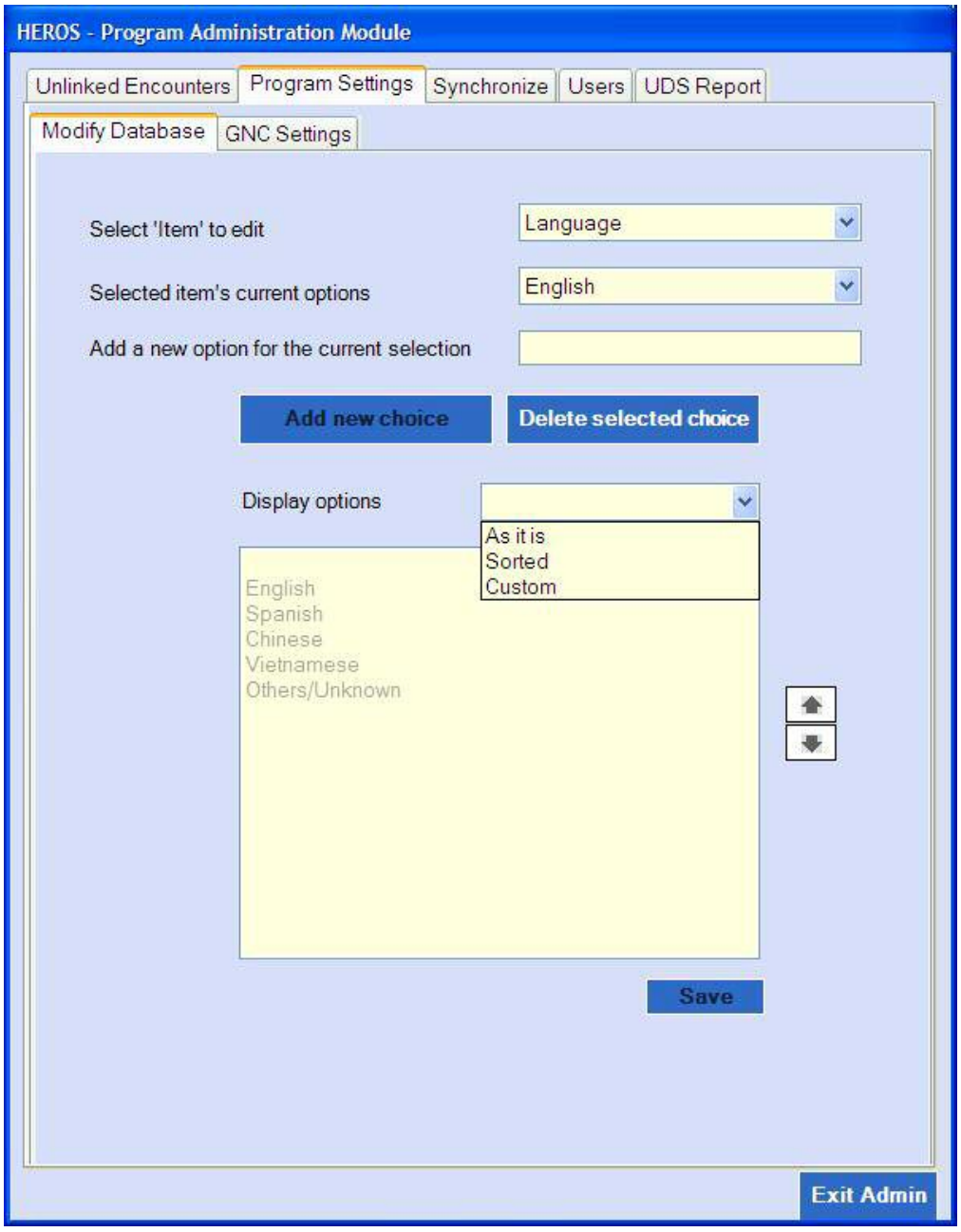

Figure 19 Control Program Settings – Modify Database

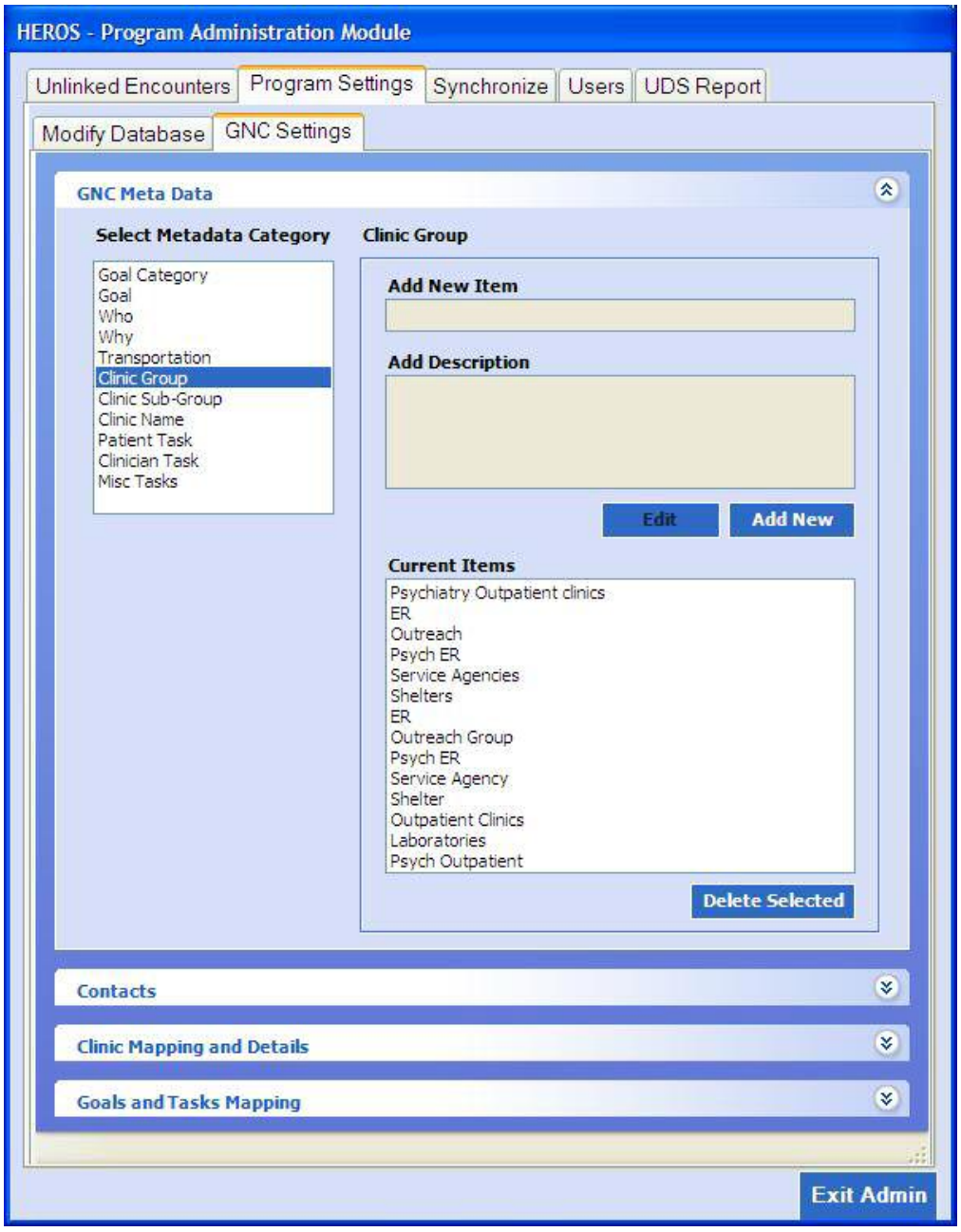

Figure 20 Control Program Settings – GNC Settings – GNC Metadata

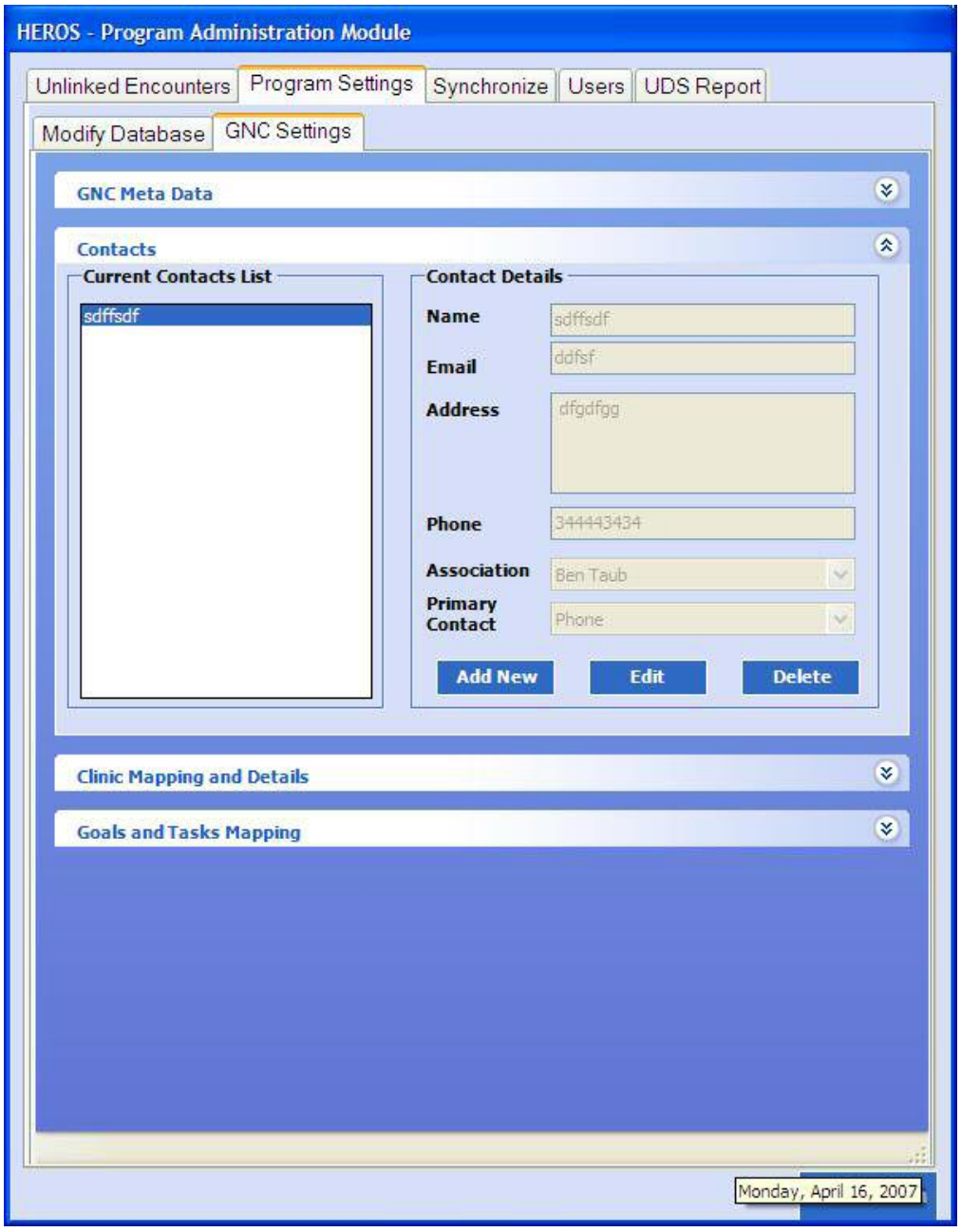

Figure 21 Control Program Settings – GNC Settings – Manage Contacts

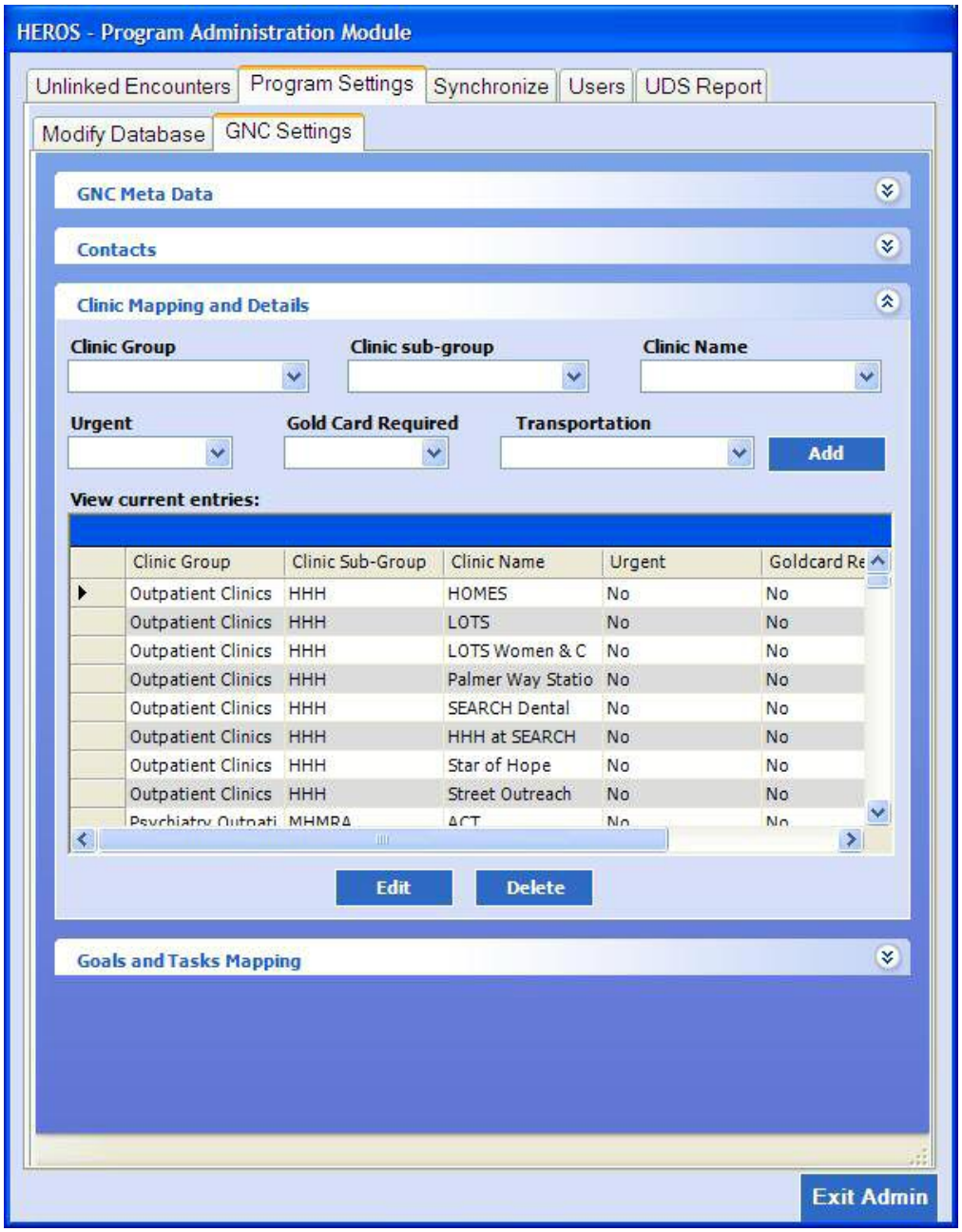

Figure 22 Program Settings – GNC Settings – Clinic Mappings

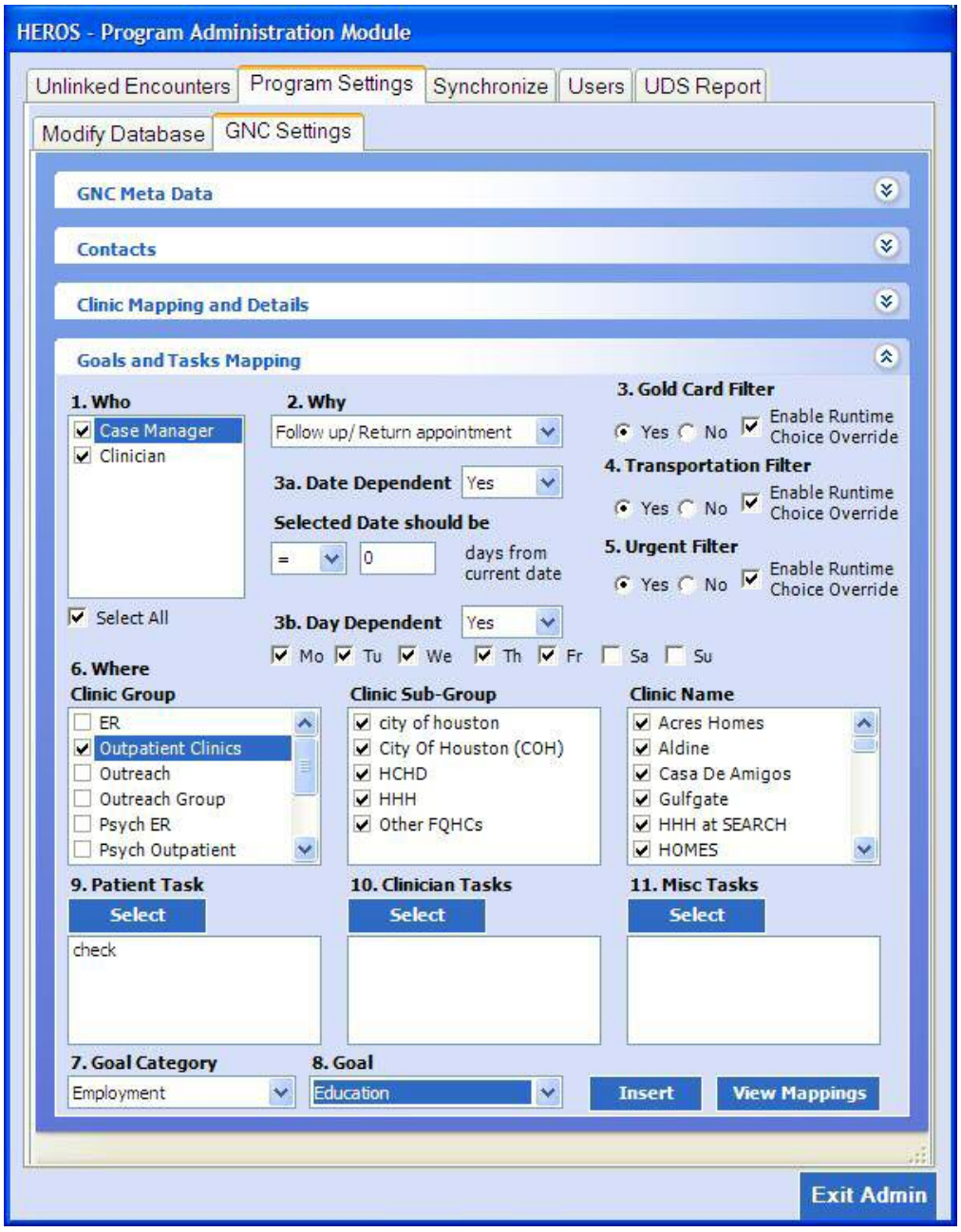

Figure 23 Program Settings – GNC Settings –GNC Mappings

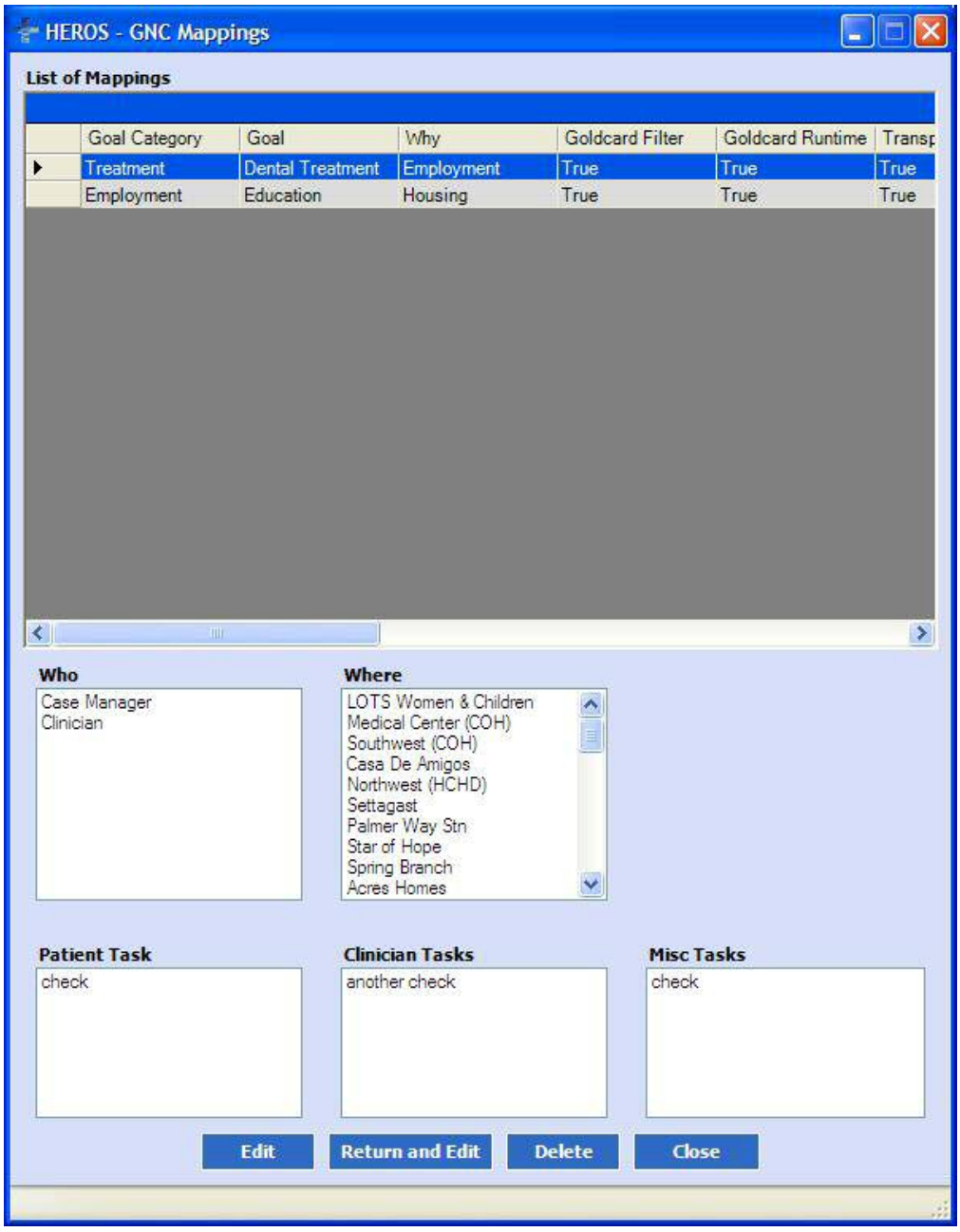

Figure 24 Program Administration - View Mappings

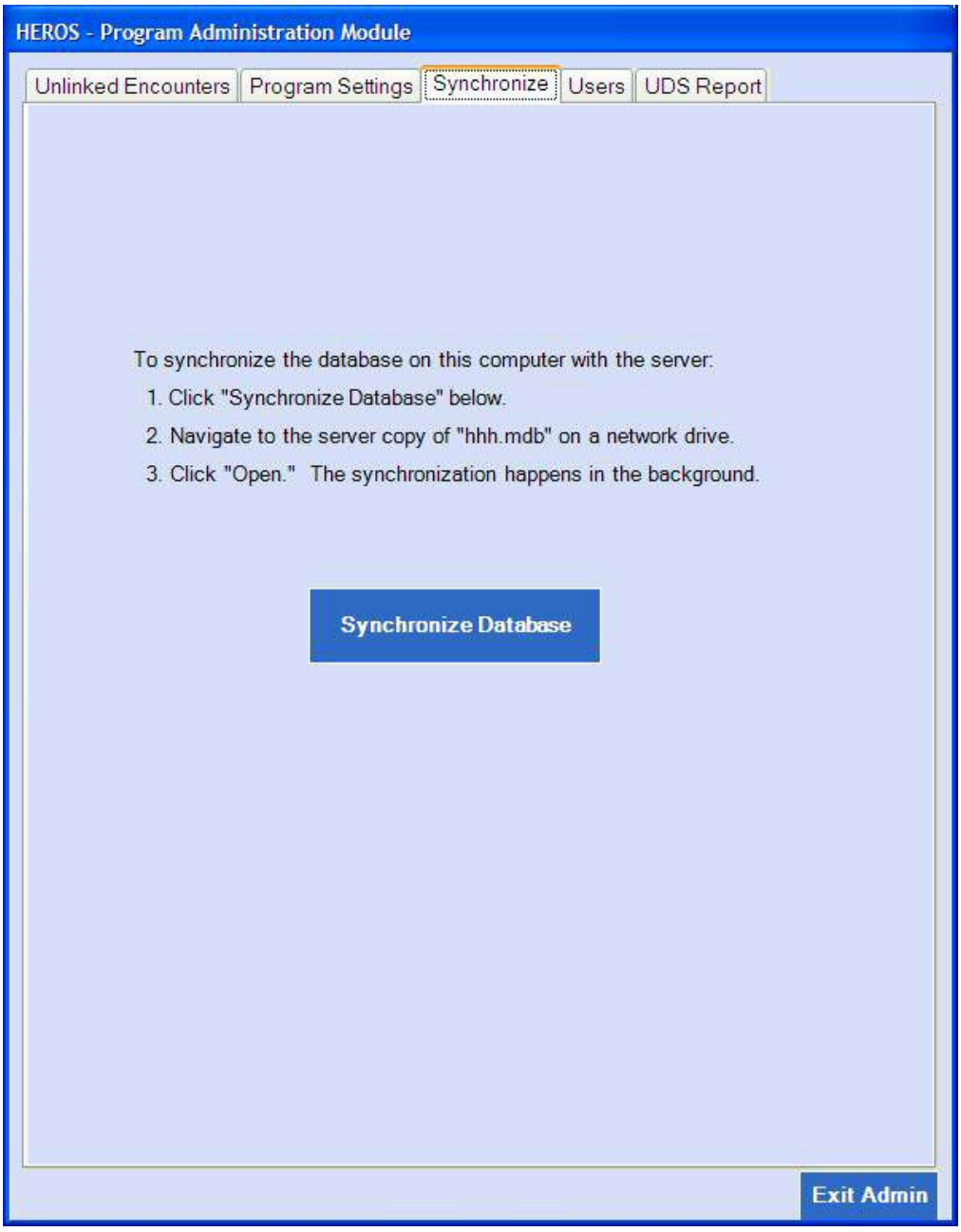

Figure 25 Program Administration - Synchronize Database

Figure 26 Program Administration - Manage Users

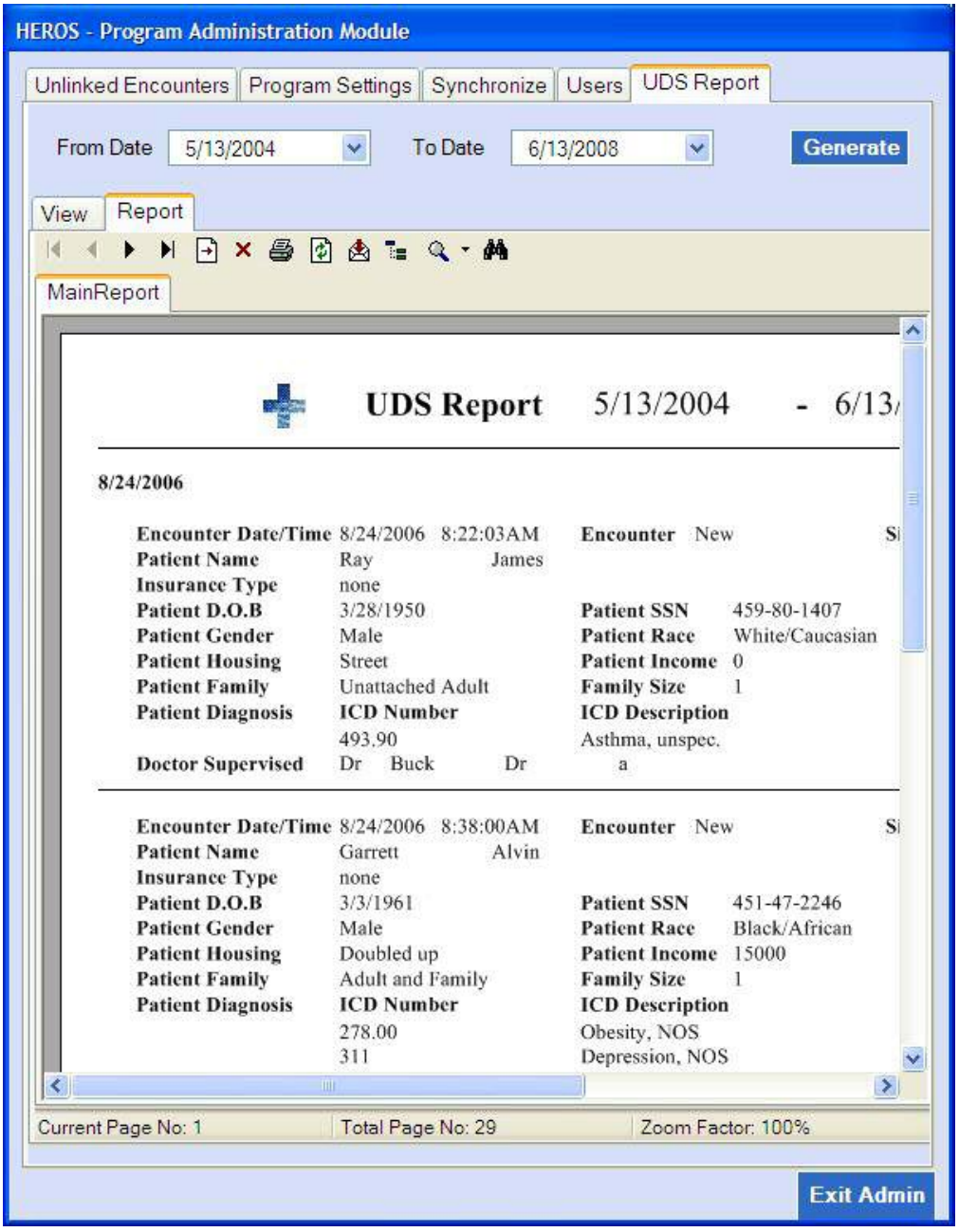

Figure 27 Program Administration - Generate UDS Report

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BIOGRAPHICAL INFORMATION

Kallol Mahata received his M.S. in Computer Science degree from University of Texas at Arlington in May 2007. He received a Bachelors Degree in Chemical Engineering from the University of Madras in May 2004. Kallol is continuing to work on a part time basis with organizations across the globe on providing better healthcare services to the homeless by the use of technology. His research interests include healthcare workflow analysis, EMR design and neural networks.