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Design and Implementation of a Multi-Institution Immunization Registry

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Abstract

One of every four children in the USA is underimmunized. Surveys of children in New York City have documented rates of appropriate immunization as low as 37% in certain populations in northern Manhattan. In response to this, government and private agencies have undertaken efforts to improve immunization rates. As part of one such multiinstitution effort in northern Manhattan, we have begun implementation of a computer-based immunization registry. Key features of this registry system include adaptation of legacy software in order to perform initial capture of data in electronic format; design of a user interface using a World Wide Web server that provides data review and capture functions with appropriate security; implementation of a registry database with links to the server, communication links between hospital registration systems, a Master Patient Index, community providers and the central registry; and integration of decision support in the form of Medical Logic Modules encoded in the Arden Syntax. We discuss our design of this multi-institution immunization registry and implementation efforts to date.

Keywords

Immunization Registry; Computer-Based Patient Record; Decision Support System

Introduction

The Immunization Problem

One of every four toddlers in the United States remains underimmunized despite a national campaign to improve vaccination coverage to 90% [1]. In the late 1980s, a survey of immunization coverage rates for children entering the school system in 20 selected urban areas found only 2 areas in which the rate exceeded 50% [2]. Indeed, eight locations had rates less than 40%, and one had a coverage rate of 11%.

In response to such data, many agencies undertook efforts to improve immunization rates. For example, in the US State of Georgia, individual clinics used a variety of incentives, including reminder-recall systems, linkages with supplemental nutrition programs and even awarding plaques for attaining coverage goals [2]. In part because of these innovations, median series-completion rates at public clinics rose from 53% to 89% [2].

Moreover, immunization information systems have been advocated as a key component of this and similar efforts to improve immunization rates [3]. Consonant with this idea, other workers have created software to assist in this effort. Workers elsewhere have created a World Wide Web interface for an immunization registry [4]. Another project, IMM/Serve, is a rule-based program that can identify underimmunized patients in a registry [5]. The New York City Department of Health (NYC DOH), working with a private vendor, is also in the process of creating an immunization registry.

In parallel with such work, the US Centers for Disease Control and Prevention (CDC) created a program to study cooperation between academic medical centers and community providers and organizations in seeking to improve immunization rates. Four sites in the USA were awarded projects in 1996, including three urban centers and one rural center. We are participants in one such urban project to improve immunization coverage through a variety of mechanisms in the northern part of Manhattan in New York City. Key to this effort is the development of a multi-institution immunization registry.

The Registry Setting

The setting for the registry is a network of three hospitals in northern Manhattan, all affiliates of Columbia University. These are the Columbia-Presbyterian Medical Center (CPMC), Harlem Hospital Center (HHC) and St. Luke's -Roosevelt Hospital Center (SLRHC). The catchment area of these institutions and affiliated providers include three distinct neighborhoods in northern Manhattan with a total population of 404,689 (1990 US Census data). The population of Washington Heights/ Inwood, the largest of these neighborhoods, is 67% Hispanic, most of whom are Dominican. By contrast, Central Harlem has a population that is 88% African-American, while West Harlem's population is more mixed (39% African-American, 36% Hispanic) than the other two districts. The annual number of births in the three areas, and hence the potential number of new entries into the registries aside from immigration, is 8839 (1990 US Census data). These areas have high rates of poverty, including 28% of households in Washington Heights/Inwood. In addition, linguistic isolation in the form of poor facility in English is prevalent in this community.

These areas also have low rates of immunization. In a 1993 cluster community survey of Washington Heights/Inwood, vaccination coverage for children under six years of age was only 44% for the 4-3-1 series. Audits conducted in 1995 by Harlem Hospital Center at its primary care clinic showed a coverage rate of only 37% for children older than 15 months for the same series.

Purpose of the Project

The overall goal of the project, then, is to improve significantly these poor immunization coverage rates in areas served by the three participating institutions. This will be attempted by a variety of means, including outreach to community organizations that can identify underimmunized children; audits of provider records coupled with feedback to identify missed opportunities for immunization; and outreach to non-primary-care sites such as nutrition programs and school-based clinics that see large volumes of pediatric patients.

However, the mainstay of the project is the creation of a multi-institution immunization registry. This will permit providers to enter immunization and demographic data; review past immunizations, including those administered at other sites; receive recommendations on when to administer subsequent vaccinations, i.e., forecasting; and receive reminders to vaccinate those children who are underimmunized. In addition, this system will permit easy audits in order to study immunization rates among various providers and subpopulations and allow feedback.

Key features of this registry system include adaptation of legacy software in order to perform initial capture of data in electronic format; design of a user interface using a World Wide Web server that provides data review and capture functions with appropriate security; implementation of a registry database with links to the server; communication links between hospital registration systems, a Master Patient Index, community providers and the central registry; and integration of decision support in the form of a clinical event monitor using Medical Logic Modules (MLMs) encoded in the Arden Syntax. These features are displayed in Figure 1

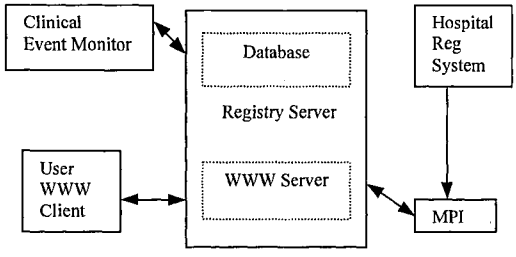

Figure 1 - System Schema. WWW is World Wide Web. MPI is Master Patient Index. Reg is Registration. The registration system and user client are multiply instantiated.

Here, we detail the architecture of this system. We also review progress of its implementation to date. In addition, we outline future work yet to be accomplished. Because of the potential for knowledge sharing in the use of the Arden Syntax in a rule base and because the challenges we face, including unique patient identification and user interface design, are common to any multi-institutional information system, we believe that our efforts can offer potential lessons to other workers. Ultimately, we hope that this complex system will help us meet our goal of significantly improving immunization coverage rates in northern Manhattan.

Materials and Methods

Adaptation of Legacy Systems

Before the proposed registry could be activated, physicians in New York City were mandated by law to begin reporting immunizations for children under eight years of age to the NYC DOH. In order to minimize this regulatory burden for hospital-based providers at the three institutions, we and workers at HHC and SLRHC created interfaces to extant registration and billing systems in order to retrieve immunization information already being captured in electronic format from encounter forms as part of routine practice.

These interfaces allowed the capture of a minimum data set for each immunization without significant alteration in organizational or provider practice. Included in the set is the patient name, institutional medical record number, provider, date of the immunization and which immunization is administered. While these data fulfill the minimum regulatory reporting requirements, they are inadequate for research, decision support and other purposes. However, the adaptation of these systems allowed us to begin to collect baseline data in electronic format without having to introduce new systems or activities into clinical practice.

Moreover, because of the NYC DOH regulatory mandate, these data are encoded in a standard, electronic format, the Uniform Provider Interchange Format (UPIF). This will allow us to use these data from all participating institutions without alteration in order to populate our registry for study of baseline immunization rates.

User Interface

We designed a prototype interface using the World Wide Web motif. We implemented this using JavaScript and C++. In order to speed system response time, we minimized the amount of graphics so that downloading Web pages would not slow the practice of a pediatrician or nurse in a busy clinical practice.

The user interface provides two important functions: immunization data review and data capture. We designed an "immunization-at-a-glance" page so that providers can quickly ascertain a patient's immunization status. In addition, we provide a display of recommended immunizations based on output from the CPMC decision support system using Arden Syntax MLMs.

The data capture mechanism provides site-specific defaults such as vaccine manufacturer name and lot number in order to minimize the amount of data entry needed. Such data change only infrequently at each clinic site and are easily maintained in our central database. In addition, we provide pick lists with default values, such as the date of administration and body site of injection, so that nearly all immunizations can be entered with merely a few clicks of a pointing device.

The user interface design also provides a mechanism for printing a record of vaccine administration, in Spanish when necessary, that a parent can keep as proof of immunization. In addition, a record of immunizations can be printed for each provider for inclusion in the paper-based patient record.

In addition to the built-in security features of the Netscape browser, the user interface provides security by requiring a valid password and identifier for access. Also, hidden session identifiers are maintained in order to provide a session time-out feature and to prevent unauthorized access to the registry.

Registry Database

Using the UPIF and data elements specified in the CDC's *Community Immunization Registries Manual,* we determined the set of elements necessary to represent immunization information adequately. Using this set, in turn, we designed a relational database that can accommodate these data elements. In addition, we updated CPMC's electronic medical vocabulary, the Medical Entities Dictionary (MED), with missing concepts when appropriate. We use the MED to identify data elements uniquely for database storage and retrieval.

Subsequently, we created links between the Web server and the database in order to permit rapid storage and retrieval of data. Finally, we designed links to the central CPMC repository, where the project's decision support engine also resides, so that data are mirrored in this central repository and widely available, with the usual password security, to providers throughout the institution.

Communication Links

In order to receive demographic and visit information on the significant majority of our patients who see hospital-based providers, we designed communication links to the registration system of each participating hospital. As patients are born, admitted to the hospital or are registered for an outpatient visit, clerks at the appropriate institution record these events using extant software packages. This software then generates a message in standard HL7 format, using the patient identifier assigned by the institution that is generating the information. Interfaces at each site can filter these messages so that only HL7 messages of certain types (generally ADT referring specifically to registration or visit information) on certain patients (pediatric patients in the correct age range) are forwarded.

These messages then are transported over leased lines to a geographically separate server that executes STC Datagate. This module functions as the MPI for the project. Patient information in the message, such as name, date of birth, sex, mother's maiden name and other elements are used to determine if the patient already has a matching identifier in the system. If no previous registration is matched with high probability, a new unique identifier is assigned from a pool of identifiers reserved for this purpose. Potential duplicate identifiers, i.e., sets of data elements that match closely but not with very high probability, can be written to log files for later manual review and, if needed, deduplication. Once an appropriate MPI identifier has been assigned, it is substituted for the original local identifier in the message, and this original identifier is written to an alternate slot in the HL7 message.

The message is then transported over another leased line to the central registry, where it is stored in the relational database after tagging its data elements with standard codes from the MED. A mirror copy of the message is also stored in the CPMC central repository, which is linked to the project's decision support system.

In addition to these inter-hospital communication links, the architecture of the overall system incorporates mechanisms for connecting individual offices to the registry. A significant majority of participating offices are owned or affiliated with one of the participating hospitals. These offices already have network connections to the relevant hospital wide area network (WAN), which in turn will be connected to the registry via the aforementioned leased lines. In addition, these providers already use the hospitalbased registration system.

Beyond this, a certain number of participating providers are community-based physicians with private practices that are not connected to a hospital WAN. For these providers we have designed a desktop incorporating a personal computer and connectivity to an Internet Service Provider (ISP) which in turn will provide access to our Web server. To the extent that such communications travel over the Internet, this network traffic will be encrypted for security purposes.

Because these community-based providers do not currently have electronic registration systems, we provide a module in the user interface that permits such users to register patients in the immunization registry. The design for this mechanism incorporates invocation of the MPI in order to reduce the probability duplicate identifiers.

Finally, in order to collect data on our registry's patients that may have been submitted by providers not participating in the registry, we are negotiating with public agencies for periodic batch download of immunization data and death certificate data on registry patients.

Decision Support

Our system architecture incorporates links to the CPMC decision support system. The rule base for this system is encoded in the Arden Syntax. The hospital registration system will send a message to the decision support system, a clinical event monitor, each time a patient appears for a visit. This will trigger appropriate MLMs, which in turn will generate a list of recommended vaccinations at that time and the scheduled dates for future vaccinations. The provider can display these when he or she accesses the patient record via the Web-based user interface.

In addition, MLMs will be triggered periodically that will examine registry data independent of patient visits in order to identify patients who are underimmunized at that time. Notification of these discoveries can be made by sending a letter to the patient's home, using demographic data already captured. In addition, providers can be notified via fax or electronic mail.

MLMs will be maintained in accordance with changing guidelines for administration of childhood vaccines so that the advice provided by the decision support system will consistently reflect the latest accepted guidelines.

Results

Implementation-to-Date

Adaptation of legacy registration and billing systems has been accomplished at all three participating hospitals. At the CPMC site alone for the initial period of January 1 through June 30, 1997, this captured data on 16,529 immunizations for 3738 distinct patients aged 8 years and younger during 5457 visits. These systems are used to report data to the NYC DOH in the UPIF.

We created a prototype user interface in a Web motif. We performed a formative evaluation of the interface among selected potential users of the system and incorporated their suggestions for changes into the design. We incorporated security features, including password protection and hidden session identifiers, into this design.

We implemented a relational database design incorporating storage for data elements recommended by authoritative organizations. We modeled these data elements in the MED and created concepts in the MED for some immunizations not previously represented there. We then created software linking this database to the Web server and the user interface.

We have specified the communication pathways between the hospital registration systems and the MPI as well as between the MPI and the registry. Where necessary, the leasing of these lines is currently being implemented. We have created the software necessary to interpret incoming messages from hospital registration systems and user interfaces and store these data in the immunization database as well as the CPMC central repository.

We have specified the communication links, including desktop features and network communication, for community providers currently not using a WAN. We currently are finalizing purchase of this equipment and services. Finally, we have begun translating guidelines for childhood immunizations into MLMs in the Arden Syntax.

Future Work

We will complete the communication linkages between providers, hospitals and the registry. We will complete the translation of vaccination guidelines into MLMs. We will test novel input devices, such as bar code scanners, that will permit direct entry of vaccine information from their packaging without the need to choose from a pick-list or to maintain a list of default values for manufacturer name and lot number. We will finalize arrangements for data transfer from NYC regulatory agencies, such as death certificate data. Finally, with the decision support component fully in place, we will test whether providing access to an immunization registry in a multi-institution setting with reminder/recall and forecasting features will improve rates of immunization coverage.

Discussion

The real test of any electronic patient record, such as the interactive immunization registry that we have designed and partly implemented, is whether providers will use it in actual practice. After consulting multiple providers and eliciting their feedback, we have created a system that we believe will be used in practice. By minimizing graphics, by focusing on simple but complete summary displays and by facilitating immunization data capture through the use of pick-lists and defaults, we believe that the system can be used with minimum disruption of workflow.

Moreover, use of the system provides significant added value that also should facilitate its use. Automated forecasting makes guideline compliance easy. Automated reminder and recall strategies eliminate costly manual systems for tracking patients and detecting underimmunized patients. By capturing data in the registry, providers can fulfill governmental regulatory requirements with minimal additional effort. In addition, by providing printed records for patients, the registry system can fulfill an educational function. Also, documentation for paper-based patient record systems is automatic. Moreover, by linking data from multiple institutions and from New York City at large, the registry will supply data to each provider on all immunizations provided to the patient regardless of site, thus helping to ensure complete documentation of immunizations.

Of course, the system presents a number of challenges in the face of these benefits. One important issue is the success of the MPI. Duplicate patient identifiers will lead to fragmented data collection and inaccurate reminder/recall activity. This in turn will reduce acceptability of the system as providers have difficulty viewing all of a patient's immunizations and as they receive inappropriate reminders for vaccination. By monitoring the MPI software and performing periodic manual reviews, we hope to minimize the scope of this problem.

One potential benefit of this registry is its use of Arden Syntax MLMs. The Syntax provides the only standard mechanism for sharing procedural medical knowledge. By creating and validating MLMs that incorporate vaccination guidelines, we hope to share these MLMs with other institutions that use Arden, thus maximizing the potential impact of our work and promoting adherence to recognized clinical guidelines.

Conclusions

Generally, childhood immunization coverage rates in the USA are poor. This is particularly true for our geographic region of northern Manhattan in New York City, which region is primarily populated by poor and minority residents. In order to study and help improve this situation, we have designed and partly implemented a multi-institutional immunization registry that collects and provides vaccination data to physicians affiliated with three hospitals serving a combined population of over 400,000 persons.

Key features of this registry system include adaptation of legacy software in order to perform initial capture of data in electronic format; design of a user interface using a World Wide Web server that provides data review and capture functions with appropriate security; implementation of a registry database with links to the server; communication links between hospital registration systems, a Master Patient Index, community providers

and the central registry; and integration of decision support in the form of MLMs encoded in the Arden Syntax.

We have implemented a sizeable portion of this architecture. In the near future we will complete this implementation and begin study of the effectiveness of the system in improving immunization coverage rates in northern Manhattan.

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