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Informatics Lessons from Using a Novel Immunization Information System

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Abstract

In the 1990s, NewYork-Presbyterian Hospital began developing a comprehensive, standards-based immunization information system. The system, known as EzVac, has been operational since 1998 and now includes information on 2 million immunizations administered to more than 260,000 individuals. The system exchanges data with multiple electronic health records, a public health immunization registry, and a standalone personal health record. EzVac modules have recently been incorporated into the OpenMRS application and are being used to enhance immunization efforts in developing nations. We report on our experience with developing and using the EzVac system for 1) clinical care, both in local and global settings, 2) public health reporting, 3) consumer engagement, and 4) clinical and informatics research. We emphasize the advantages of using health IT standards to facilitate immunization information exchange in each of these domains.

Keywords:

Health information exchange, immunization, health information system.

Introduction

Poor management of immunization information is a major reason for under- and over-immunization. Nearly one in four U.S. toddlers does not receive the prescribed basic immunization series [1], while thousands of children unnecessarily receive duplicate vaccinations [2]. Immunizations are administered over the course of a lifetime by a variety of healthcare providers. Approximately 25% of U.S. children see more than one immunization provider in their first three years of life, causing fragmented and incomplete vaccination records [2, 3].

The use of electronic immunization registries has been recommended to consolidate vaccination records and facilitate information exchange. Our institution, NewYork-Presbyterian Hospital, is a large, urban academic medical center in New York City that cares for an underprivileged and medically underserved population. The institution established a local immunization registry in 1998 [4, 5] that now contains information concerning over 2 million immunizations administered to over 260,000 children, adolescents and adults. The registry, known as EzVac, includes a database server, a Web-based application, and a set of services that support data and workflow integration with other systems and applications.

The EzVac system supports clinical care, public health reporting, consumer engagement, and clinical and informatics research. Recently, an EzVac module has been incorporated into the open-source electronic health record (EHR) known as OpenMRS. The module provides patient-specific immunization recommendations in developing nations. The recommendations are accessed by clinicians and community health workers using mobile technologies.

This paper describes the informatics challenges and lessons learned during nearly 15 years of collecting, using, and exchanging electronic immunization information.

Materials and Methods

Figure 1 illustrates the functions provided by the EzVac immunization information system. The system exchanges immunization data bi-directionally with New York City's Citywide Immunization Registry (CIR). The goal of CIR is to improve the immunization status of all children in New York City by consolidating immunization information and sharing it with healthcare providers, families, and agencies concerned with children's health. The CIR was implemented in 1997 when the New York City Health Code began requiring providers to report all immunizations administered to children age 7 and younger to the city's Department of Health and Mental Hygiene. In 2005, the mandatory reporting age was extended through age 18. Thus, the data exchange between EzVac and CIR fulfills a local public health reporting requirement, and also assures that our institutional records contain immunizations administered to our patients elsewhere in the community. Receiving information from the CIR ensures a more complete immunization record and reduces the likelihood of over-immunization.

EzVac has been independently certified by the Certification Commission for Health Information Technology (CCHIT) to fulfill the U.S. "Meaningful Use" criteria for submitting electronic immunization data to immunization registries. The EzVac system also helps our institution to fulfill the reporting requirements of the U.S. Vaccines for Children program, which provides free vaccines to patients in financial need.

The Web-based EzVac application used by clinicians is shown in Figure 2. Hundreds of physicians and nurses use the application in ambulatory and inpatient care settings, to review vaccinations and to automatically generate forms required for enrolling children in school, daycare, summer camp, and the U.S. Women, Infants and Children (WIC) program. EzVac also facilitates vaccine adverse event reporting by generating forms used by the U.S. Food and Drug Administration's Vaccine Adverse Event Reporting System.

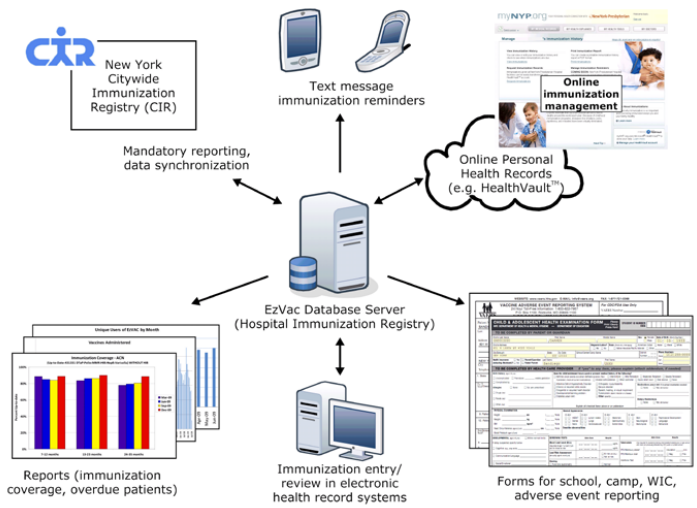

Figure 1 - Architecture and functions of the EzVac immunization information system.

EzVac also supplies immunization information directly to consumers via myNYP.org, an online personal health record (PHR) that stores data using Microsoft HealthVault. To ensure patients are up-to-date with their immunizations, a text-message reminder system was developed to notify individuals when a vaccination is due [6-8].

In addition to functioning as a standalone web application, single sign-on and patient context passing exists between EzVac and two commercial EHRs used at our institution. Vaccine orders entered in the inpatient EHR (Sunrise Care Manager, Allscripts Corp., Chicago IL) and the outpatient EHR (Epic Care, Epic Systems, Madison WI) are transferred to the EzVac database using custom data extraction programs. Vaccines are represented as HL7 CVX codes, and also modeled using terms in our institution's Medical Entities Dictionary [9]. Provenance is established by tagging each immunization with a field identifying its source system.

Data are exchanged with the Citywide Immunization Registry via HL7 messages. When EzVac reports immunization data to CIR for an individual for the first time, CIR employs a matching algorithm to determine whether the individual already has a record of immunizations in the registry. If not, a new record is created and a unique identifier is sent back to EzVac; this identifier is used in subsequent exchange messages. Immunizations administered at our institution are submitted in a daily batch to CIR. Retrieving immunization data from CIR and appropriately merging those data into the EzVac database occurs dynamically whenever a patient's immunization records are viewed by a clinician.

EzVac contains functionality that provides patient-specific decision support as to whether an immunization is required at a particular date based on his/her previous vaccination history. In 2012, this functionality (in the form of a Java module) was incorporated into the OpenMRS EHR, which sits at the center of the Millennium Villages Global Network [10]. OpenMRS is a standards-based, open-source enterprise electronic medical record system that is being implemented in more than 50 countries. The EzVac module in OpenMRS allows system administrators to add country-specific immunization guidelines easily into the EHR. By mapping immunizations to the appropriate CVX codes, patient-specific immunization reminders can be generated, regardless of which country is using the module.

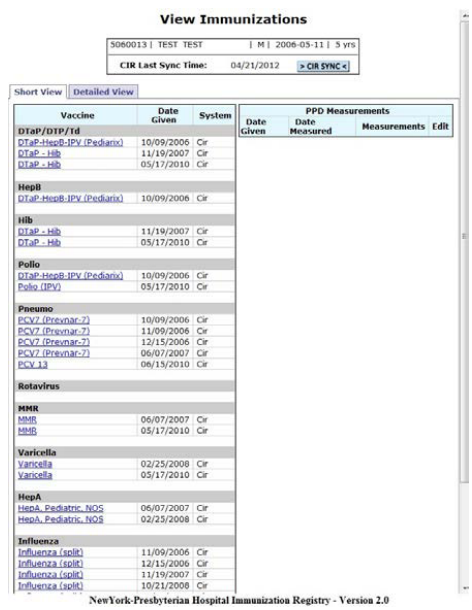

Figure 2 - Web-based portal for the EzVac immunization information system. The application is integrated with commercial EHR systems.

Results

Benefits of the EzVac system have been identified in the domains of clinical care, public health reporting, consumer engagement, and clinical and informatics research.

Clinical Care

New York City

Over 1,000 physicians and nurses use EzVAC each month to review immunization histories, document new and historical vaccinations and generate forms required for enrollment in school, daycare, summer camp, and the Women, Infants and Children (WIC) program. The highest volume of EzVac use is in our institution's network of ambulatory care clinics located in New York City's Washington Heights/Inwood community.

Most residents in this community come from minority backgrounds, are not native English speakers, and rely on public insurance (e.g., Medicaid and SCHIP). Populations with these characteristics are at high risk for under-immunization.

The use of EzVac has had a positive impact on immunization rates in our community, helping us to meet the immunization coverage goal set by the U.S. Healthy People 2020 initiative (Figure 3). The Healthy People 2020 objective for childhood immunization is to achieve 90 percent coverage for each of the universally recommended vaccines among young children. For 24-35 month-old children in June 2012, our immunization coverage was 90.2%, compared to the U.S. rate of 72.0% and the New York City rate of 67.0%.

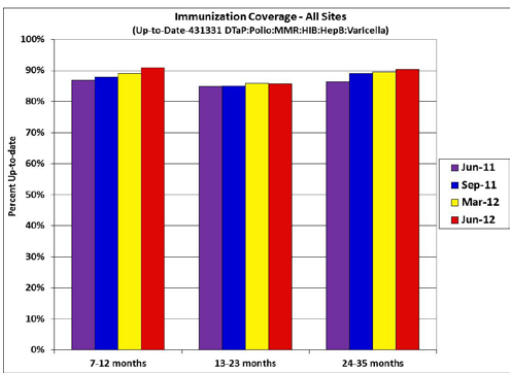

Figure 3 – Quarterly immunization coverage for the 4:3:1:3:3:1 (diphtheria-tetanus-acellular pertussis (DTaP), polio vaccine (IPV), Hemophilus influenzae type b (Hib), hepatitis B (HepB) vaccine, measles/mumps/rubella (MMR), and varicella vaccines) series in children seen in our clinics between June 2011 and June 2012.

Tanzania

The EzVac decision support module that provides patient-specific immunization recommendations is being studied in Mbola, Tanzania. To date, immunization history information has been collected for over 500 children under 2 years of age. When these children present to any of three intervention clinics, patient-specific recommendations are available to the clinic staff. Efforts are also underway in the Millennium Villages Global Network to send the same patient-specific recommendations to community health workers' mobile phones.

Public Health Reporting

In the United States, most states have their own immunization registries run by local health departments (New York State has its own registry in addition to the CIR, which is operated by New York City). The American Immunization Registry Association (AIRA) is an organization whose members represent many of the statewide immunization registries. AIRA promotes the development and implementation of immunization information systems throughout the United States. In 2011, our institution was designated as a Center of Excellence by the (AIRA).

While few would argue the benefits of mandatory reporting of immunizations administered to local public health departments, there is a cost associated with this process, especially when it involves manual effort to report each vaccination. As observed by the American Academy of Pediatrics Committee on Practice and Ambulatory Medicine, "the fiscal effect on a practice depends on whether immunization data can be directly downloaded into the immunization information system from billing information, which in most cases requires the practice to purchase appropriate software. This downloaded information would provide the date and type of vaccine to the IIS but not the other required fields, such as lot numbers, site, administering personnel, etc." [11]. EzVac facilitates the public-health reporting of immunizations administered to patients as a byproduct of existing electronic workflows (i.e., electronic ordering and electronic documentation of vaccine administration in the EHR). We estimate a savings of several million dollars in documentation time by using EzVac to fulfill mandatory reporting requirements. A 2000 study by Rask et al. reported that manually entered data would cost $3.24 per shot, compared with $0.24 if the entry were automated [12]. A 2004 study by Glazer et al. later observed an increase in cost of $0.56 per shot after implementation of immunization registry reporting, with nurses spending 3.4 minutes per shot on registry activities [13].

Consumer Engagement

One of the unique aspects of EzVac compared to other immunization repositories is its linkage to our institution's personal health record (myNYP.org). From myNYP.org, consumers can view their (or their child's) immunization record and import it into their personal Microsoft HealthVault account. In 2008-2009, we conducted focus groups with parents from an urban, primarily Latino, low-income population in New York City to determine desired characteristics of and concerns regarding an online immunization record. Parents were interested in using online immunization records but wanted safeguards to protect confidentiality and prevent unauthorized access.

Clinical and informatics Research

Many grant-supported projects and internally supported projects have benefited from using EzVac. Among them is a project to integrate electronic influenza vaccination reminders for pediatric providers into the EHR. Known as "FluAlert," the project uses real-time information from EzVac and CIR to intelligently alert providers about their patients' influenza vaccine status [14]. FluAlert also facilitates documentation of both vaccine administration and parent refusals, which is important for meeting compliance and quality improvement goals.

A text messaging research platform exists in EzVac: it has been successfully used to notify families that their child is in need of vaccination. We have shown its effectiveness with both receipt of influenza vaccination [6] as well as adolescent vaccines [8]. We have also shown its success in improving influenza vaccine coverage in pregnant women.

Other EzVac-related projects are evaluating the use of text messaging for patients to report vaccine adverse events. For example, in collaboration with the U.S. Centers for Disease Control and Prevention, EzVac researchers have assessed fever rates after influenza vaccination.

Discussion

In our experience with exchanging immunization information, we encountered several challenges, including: patient matching, standards for data exchange and interoperability, the need for reconciling information from multiple sources, and establishing data provenance and privacy controls.

Patient Matching

Many countries outside the United States have been progressive in terms of assigning each individual a unique identifier

that is used for managing health information. Because the United States does not use a unique personal identifier, it can be difficult in a health information exchange scenario to ensure that information is attributed to the correct patient. Recent recommendations from the US President's Council of Advisors on Science and Technology (PCAST) disavow the need for a uniform patient identifier, suggesting instead that a combination of factors such as name, birthdate, and social security number can be used to link the appropriate data to a specific patient [15]. Deterministic and probabilistic methods for patient matching are used today within local systems and regional health exchanges, and automated systems can use additional factors to improve accuracy [16-19].

Within our institution, EzVac relies on a master patient identifier (MPI), which uniquely identifies an individual across care settings and multiple electronic health record systems that use their own internal identification numbers. When EzVac exchanges immunization data with CIR, a separate, CIR-generated patient identifier is used. The CIR identifier is assigned the first time immunizations are reported for an individual. A deterministic (i.e., rule-based) matching algorithm (similar to that suggested by PCAST) is employed by CIR to detect whether a person already has an immunization record on file. Our experience suggests that approximately 97% of patients with recent healthcare encounters at our institution are matched correctly using the algorithm. The remaining 3% require manual review and assignation of the correct identifier. As has been documented by other investigators, some of the challenges affecting patient matching include demographic information that is outdated or incorrectly recorded, the sharing of identifiers, and identity traits that are too common to allow an unequivocal match. Our results suggest that the PCAST recommendations will work in contexts in which humans are available to adjudicate unmatched records, but that fully automated transfer will require more accurate matching and that we must consider the privacy cost of false positive matching.

Standards for Data Exchange and Interoperability

EzVac primarily uses HL7 version 2 standards for inter-application messaging. Where systems could not support HL7 interfaces, immunization administration data (including canceling of administration events entered in error) were transferred from EHRs to EzVac via a custom extract, transform and load (ETL) process. In the U.S., the federal "Meaningful Use" incentive program has hastened the efforts of commercial EHR vendors to include HL7 outbound capabilities for immunization exchange in their products.

A concerted effort over many years by the U.S. Centers for Disease Control and Prevention (CDC) and the American Immunization Registry Association has resulted in 59% of registries with capabilities to send and receive vaccination data using HL7 messaging standards. The 2009 Immunization Information Systems Annual Report (IISAR) survey conducted by the CDC indicated that 73% of immunization registries were receiving vaccination data directly from the EHRs of some vaccine providers in their geographic area]. Outside of the U.S., HL7 version 3 is widely used for exchanging health information. Version 3 has a more structured and semantically oriented organization than version 2, and use of the version 3 standard should mitigate some of the interoperability challenges that currently exist in the U.S.

At the terminology level, the CDC's National Center of Immunization and Respiratory Diseases developed and maintains a code set known as CVX that contains active and inactive vaccines available in the U.S. While CVX codes are generally useful for standardizing the nomenclature of vaccine administration, our experience with EzVac has uncovered some limitations, specifically when dealing with combination vaccines (which combine multiple immunizations into a single shot), and vaccines that lack granularity in specification (such as pneumococcal, unspecified formulation). The CVX code set does not contain information about the relationship between vaccines—for example, that a monovalent DTaP vaccine protects against Diphtheria, Tetanus and acellular Pertussis the same way a combination vaccine containing DTaP does. Similarly, with CVX codes alone, one cannot infer that the pneumococcal, unspecified formulation code might be construed as a superset of pneumococcal vaccines with a formulation specified. Terminology development will therefore remain an iterative process, with enhancements added as use cases demonstrate new needs.

Reconciling Information from Multiple Sources

Robust, efficient health information exchange requires the ability to appropriately merge information from multiple sources. One of the important benefits of adherence to standards for data interoperability is a reduction in the manual work required to reconcile data from multiple systems. At our institution, when EzVac imports data from EHRs or the CIR, a de-duplication process is performed to mark as invisible those immunizations that have a high degree of overlap with existing immunizations in an individual's record. We consider two vaccines to be "duplicate" if they belong to the same class (as defined in our local Medical Entities Dictionary) and they were given within a 10-day window. Similarly, in the OpenMRS module, CVX codes are used to detect duplication. We have created a set of rules governing which data should take precedence when merging immunization events and eliminating duplicates, such as prioritizing combination vaccines over single-dose administrations.

Provenance

EzVac has employed a minimalistic and practical approach to establishing data provenance. Each immunization is tagged with a source field, which contains either the name of the EHR system supplying the data, the CIR, or, in the case of our PHR application, a marker for "Patient-entered" data. In the PHR application, each immunization is digitally signed by the institution when an individual requests his or her data to be transferred to HealthVault. If the individual makes subsequent changes to any field in the immunization event (e.g., vaccine, date of administration, side effects), the digital signature is modified to reflect the fact the data were changed.

Our experience with provenance in EzVac suggests that even a very shallow approach (i.e., assigning the "source," or originator of the information along with a digital signature) is helpful for clinicians. Adoption of increased metadata tagging and cryptographic assurance can be done in an incremental manner as standards are defined and best practices evolve.

Conclusion

With respect to immunization information, we identified lack of interoperability among electronic systems as a barrier to engaging patients and improving care. The EzVac immunization information system used at our institution demonstrates some of the benefits and challenges of health information exchange among multiple electronic health record systems, a public health immunization registry, and a standalone personal health record. The incorporation of EzVac logic into OpenMRS demonstrates the importance of adhering to health IT standards and allows many more users to customize and

take advantage of the decision-support to improve immunization management.

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