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"In Medicine one must pay attention not to plausible theorizing but to experience and reason together. . . . I agree that theorizing is to be approved, provided that it is based on facts, and systematically makes its deductions from what is observed. . . . But conclusions drawn from unaided reason can hardly be serviceable; only those drawn from observed fact."

—Hippocrates, *Precepts*

The Success of an Immunization Information System in the Wake of Hurricane Katrina

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ABSTRACT

Within days after Hurricane Katrina in September 2005, the Houston-Harris County Immunization Registry was connected to the Louisiana Immunization Network for Kids Statewide. This linkage provided immediate access to the immunization records of children who were forced to evacuate the New Orleans, Louisiana, area. One year later, >18 900 immunization records have been found, representing an estimated cost savings of more than \$1.6 million for vaccine alone and \$3.04 million for vaccine plus administration fees. This experience demonstrated the vital and previously unrecognized functionality of immunization information systems in a public health emergency. Here we describe the Houston-Harris County Immunization Registry's experience after Hurricane Katrina in terms of maximizing the use of immunization information systems and the implications of this experience for patients, providers, and public health for future disaster-preparedness planning.

IMMUNIZATION INFORMATION SYSTEMS (IISs) are confidential, population-based computerized information systems that collect immunization data for all children and, in some cases, adults within a geographic area.¹ IISs are currently under development or are actively being used in every state in the United States.² An innovative use of IISs was achieved during the public health emergency after Hurricane Katrina.

Before Hurricane Katrina, the development and use of IISs centered on several key purposes:

1. consolidating children's immunization histories that have been fragmented between multiple providers;
2. helping providers to "forecast" which immunizations are due for a child;
3. recalling children who are due or overdue for immunizations;
4. assisting providers to determine immunization coverage levels;
5. generating complete and official immunization certificates;

6. identifying pockets of need in the community; and
7. avoiding underimmunization or overimmunization.

Participation in IISs has steadily increased over the past decade. In 1999, 46% of public providers and 13% of private providers used IISs compared with 75% of public providers and 44% of private providers in 2005 (D. Bartlett, MPH, Centers for Disease Control and Prevention [CDC], written communication, October 10, 2006).³ The Healthy People 2010 goal for IIS participa-

Key Words: immunization information systems, childhood immunizations, public health preparedness

Abbreviations: IIS, immunization information system; CDC, Centers for Disease Control and Prevention; HH CIR, Houston-Harris County Immunization Registry; LINKS, Louisiana Immunization Network for Kids Statewide; HL7, Health Level Seven; MCIR, Michigan Care Improvement Registry

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tion is $\geq 95\%$ of children younger than 6 years.⁴ The number of children younger than 6 years with at least 2 doses recorded in an IIS has increased from 32% in 1999 to 56% in 2005 (D. Bartlett, MPH, CDC, written communication, October 10, 2006).

IISs have been found to be most useful in consolidating fragmented records from different providers in the community, region, or state.⁵ One study suggests that 25% of children receive immunizations from more than 1 provider by the age of 3 years.⁶ As a result, providers often have incomplete or inaccurate immunization records. Such fragmentation of immunization records leads to missed opportunities, duplicate immunization, and inaccurate measurement of coverage levels. In 1 study, researchers used registry immunization records from private-provider practices, community health centers, and public health clinics to determine the impact of a regional registry on overall up-to-date rates for children aged 24 months. As more children aged 7 to 24 months visited multiple provider sectors, they found that record fragmentation among the 3 sectors increased. When they sequentially added immunization-registry records from community health centers and public health clinics to records of children who had immunizations recorded at private practices, the relative increase in the overall up-to-date rate ranged from 9% for children 7 months of age to 50% for children 24 months of age.⁷

In addition, IISs assist with the management of vaccine supply, reduce missed opportunities, and generate complete vaccine records for patients, parents, providers, and schools.⁷⁻⁹ By using forecasting algorithms, IISs can also identify which immunizations are due. This basic function facilitates the implementation of reminder/recall systems, which have been shown to improve immunization rates by 1% to 20% in a variety of medical settings.¹⁰⁻¹⁵

By decreasing immunization record fragmentation and using functionalities of IISs such as forecasting and reminder/recall, providers can eliminate underimmunization or overimmunization of children. Feikema et al⁶ found that 21.1% of children were overimmunized for

at least 1 vaccine in 1997, which represented ~ 1.8 million extra doses. Results from an assessment of the benefits from using an immunization registry to determine inner-city immunization rates for infants showed that 19% of the study infants had received additional immunizations.¹⁶ Reducing the number of duplicate immunizations administered annually by using state- and community-based IISs would result in a cost savings of \$26.5 million for extra doses administered, vaccine waste, and extra clinic visits.⁶

NEWLY RECOGNIZED VALUE OF IISs

A new and powerful utility for IISs emerged in the wake of Hurricane Katrina. In the immediate days after this devastating event, $\sim 200\ 000$ evacuees from the greater New Orleans area headed for Houston, Texas. Most evacuees arrived with few personal belongings. Needless to say, most children's immunizations records were left at home.

In an effort to assist patients' families to find their children's records, the staff of the Houston-Harris County Immunization Registry (HHCIR) contacted the vendor for HHCIR and the Louisiana Immunization Network for Kids Statewide (LINKS) to inquire about connecting the 2 systems. Importantly, both registries were already following Health Level Seven (HL7) standards. HL7 is a nationally recognized standard for electronic exchange of health-related data between computer systems.¹⁷ Using HL7, a bridge was built between the 2 IISs in < 24 hours. Programmers diligently tested the connection, and the HHCIR-LINKS connection went live on September 9, 2005, a mere 10 days after landfall of the hurricane.

To assist public health officials in searching for children's immunization records, the Web-based immunization registry was made available to providers in the makeshift medical clinics in the Astrodome and George R. Brown Convention Center. Health care workers at these shelters were able to readily access records for children by using the HHCIR-LINKS connection. Figure 1 shows the cumulative number of LINKS immunization records searched and found according to month using

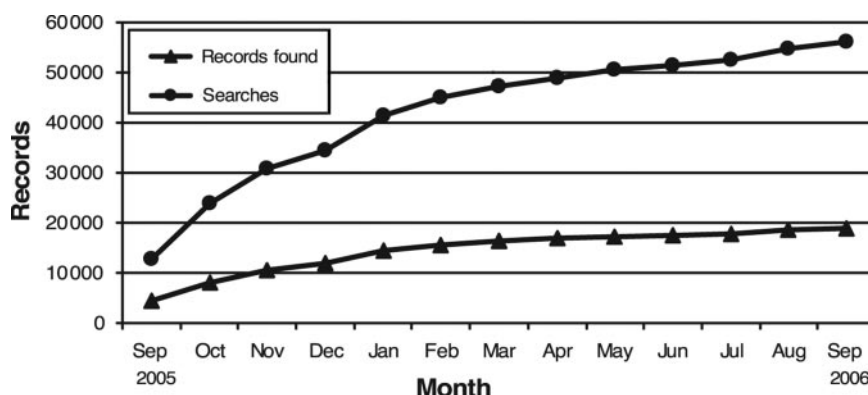


FIGURE 1
Cumulative number of LINKS immunization records searched and found in the months after Hurricane Katrina (September 2005 to September 2006).

the HHCIR-LINKS connection. One year later, 18 966 records have been found for Louisiana residents, both children and adults, because LINKS is a lifetime IIS.

The HHCIR-LINKS connection prevented children from receiving duplicate immunizations. Immediately after the disaster, children were allowed to enroll provisionally in Texas schools without proof of immunization. This provisional enrollment expired on October 31, 2005, approximately 9 weeks after the disaster. Figure 2 shows the number of LINKS immunization records found through the HHCIR-LINKS connection each month after Hurricane Katrina. As Fig 2 demonstrates, this HHCIR-LINKS connection continued to be used after the expiration of provisional enrollment, with an increase at the beginning of the spring semester in January 2006 and again at the beginning of the new school year in August 2006.

SAVINGS ASSOCIATED WITH AVOIDING OVERIMMUNIZATION

Every LINKS record recovered through the HHCIR-LINKS connection represents money saved from revaccination of these children. If immunizations were readministered to every child for whom a record was found, the cost for vaccine supply alone would total more than \$1.60 million (Table 1). In Table 1, the Vaccines for Children Program price list (current as of October 31, 2006) was applied for all immunizations recovered through this connection. As the table demonstrates, if a vaccine administration fee of \$14.85 per dose were assumed (amount permitted per the Vaccines for Children Program), the cost of vaccine plus administration fees would total \$3.04 million. These figures are based solely on the immunization histories included in the records found through the Houston connection. LINKS data were available to providers nationwide. National cost data were analyzed by Urquhart to calculate the savings incurred by all locations that accessed LINKS data (G. Urquhart, MPH, CDC, verbal communication, November 6, 2006).

The costs calculated here reflect the costs associated with avoiding overimmunization, which denotes only a partial cost analysis for the connection created between

HHCIR and LINKS. Although a net cost analysis is beyond the scope of this report, these calculations demonstrate that IISs can avoid some of the significant costs associated with overimmunization, a likely problem in the event of a natural disaster in which medical charts are destroyed. By using an IIS in these situations other costs savings would be realized. For example, vaccine shipment, storage, and handling, hiring of additional personnel, and allocation of physical space to administer shots to a large number of children would be avoided. Alternatively, costs were incurred to implement the HHCIR-LINKS connection, such as technical fees and training of additional personnel to use the IIS. Furthermore, the cost savings we report are a high-range estimate. It is likely that not all children for whom records were found would need all immunizations repeated, because some vaccines are not administered to older children and adults. However, this estimate of cost savings demonstrates the potential economic benefit of using IISs in public health emergencies.

IMPLICATIONS

The IIS experience after Hurricane Katrina demonstrated an important use for IISs: they can serve as an important safety net for patients, providers, and the community by storing immunization records that might otherwise be lost or destroyed. Using an IIS in such situations can help to avoid the costs associated with revaccinating children who have lost their immunization records.

Benefits to Patients

From a patient perspective, an IIS is a valuable tool to safeguard important health information that will be used throughout a person's life. Paper records that are stored in homes may be lost because of natural disasters, such as the flooding that occurred in Hurricane Katrina, or destroyed by fire, earthquakes, or other natural and manmade disasters. Furthermore, using IISs in these situations saves thousands of children from the pain and inconvenience of reimmunization, the cost of which does not have a tangible price tag. In addition, the HHCIR-LINKS connection allowed parents to avoid other

FIGURE 2
Number of LINKS immunization records found according to month after Hurricane Katrina (September 2005 to September 2006).

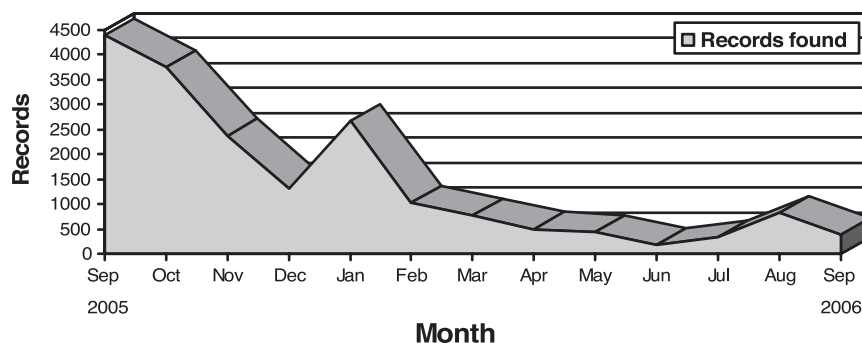


TABLE 1 Cost for the Vaccine Supply Alone and the Vaccine Supply Plus an Administration Fee for All of the Immunizations Recovered Through the HHCIR-LINKS Connection

Vaccine	N	Vaccine Price, \$	Total With No Administration Fee, \$	Total With \$14.85 Administration Fee, \$
DTaP	22 638	12.25	277 316	613 490
DTaP-Hep B-IPV	544	43.75	23 800	31 878
DTaP-Hib	621	24.94	15 488	24 710
Hep A	131	12.10	1585	3530
Hep B	13 636	9.10	1 240 088	326 582
Hib	14 990	7.92	118 721	341 322
Hib-Hep B	2292	26.25	60 165	94 201
M, R, MMR, Mu, M/R	9731	17.28	168 152	312 657
Meningococcal	18	68.00	1224	1491
Pneumococcal	5551	57.59	319 682	402 114
Polio	19 841	10.82	214 680	509 318
DT, Td	2131	16.62	35 417	67 063
Varicella	4374	56.90	248 881	313 835
Total	96 482	—	1 609 197	3 042 192

DTaP indicates diphtheria-tetanus-acellular pertussis; Hep A, hepatitis A; Hep B, hepatitis B; IPV, inactivated poliovirus vaccine; Hib, *Haemophilus influenzae* type b; M, measles; R, rubella; MMR, measles-mumps-rubella; Mu, mumps; DT, diphtheria and tetanus toxoids; Td, tetanus and diphtheria.

frustrations and costs associated with getting their children reimmunized, such as lost work time and missed school.

Benefits to the Provider

IISs serve as an important safety net to providers by preserving the medical chart. Providers in both Texas and Louisiana realized the importance of such a safety net after Hurricane Katrina. After the hurricane, >18 000 immunization records for Louisiana children and adults were found through the HHCIR-LINKS connection. Recovery of these records saved providers in Houston and Louisiana the staff time and vaccine costs that would have been required to reimmunize these children. However, there were many children whose immunization records were not available through the HHCIR-LINKS connection. As a result, providers assisted families with recovery of immunization records by contacting their Louisiana medical homes or schools, which strained limited staff time and resources. In many cases the records were permanently lost, and providers were forced to reimmunize children. By preserving the medical chart with an IIS, providers are able to serve efficiently and effectively the needs of their patients when paper records are permanently lost.

Benefits to Public Health

Finally, IISs provide an invaluable public health tool to our community. Using IISs, we can avoid revaccinating large numbers of children in the wake of a catastrophic loss of medical charts. Because newer vaccines are increasingly expensive and more vaccines are required for school entry, the loss of immunization records can represent an enormous expense to our private and public health systems. The data recovered through the HHCIR-

LINKS connection alone represented a huge cost savings to the community.

Hurricane Katrina demonstrated the usefulness of an IIS in a public health crisis involving loss of medical charts. To realize the full value of these systems in disaster situations, certain conditions must be met. First, IISs can only serve the role of a safety net if they are populated and used by patients and providers. Second, they must be technically cohesive if they are to be linked as occurred during Hurricane Katrina. Public health officials need to work toward all IISs being HL7 compliant and following the functional standards as recommended by the American Immunization Registry Association and the CDC.

Some IISs, such as the Michigan Care Improvement Registry (MCIR), have already added several functionalities that could be used in the event of a public health emergency. For example, the MCIR has an all-hazard module to quickly capture immunization data during a mass immunization campaign should an outbreak occur. Included in the all-hazard module is a “recipient tier grouping” that allows public health officials to record immunizations and medication administration data on first responders, health care workers, and essential workers during an epidemic such as pandemic influenza.

CONCLUSIONS

Our experience after Hurricane Katrina can be generalized to include any natural disaster or public health emergency. For example, public health officials can use registry data to identify pockets of need to prevent outbreaks and manage those areas should an outbreak occur. In addition, IIS functionalities such as those implemented by the MCIR facilitate effective and efficient preparation for and response to various types of public

health emergencies. Although these capabilities are not needed on a daily basis, we live in a world in which public health preparedness is vital. When IISs are fully used in a public health emergency, they yield economic benefits and strengthen our ability to serve our patients when they are most vulnerable.

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