

## P E R S P E C T I V E

**The Indiana Network For Patient Care: A Working Local Health Information Infrastructure**

An example of a working infrastructure collaboration that links data from five health systems and hundreds of millions of entries.

**by Clement J. McDonald, J. Marc Overhage, Michael Barnes, Gunther Schadow, Lonnie Blevins, Paul R. Dexter, Burke Mamlin, and the INPC Management Committee**

**ABSTRACT:** The Indiana Network for Patient Care (INPC) is a local health information infrastructure (LHII) that includes information from the five major hospital systems (fifteen separate hospitals), the county and state public health departments, and Indiana Medicaid and RxHub and that carries 660 million separate results. It provides cross-institutional access to physicians in emergency rooms and hospitals based on patient-physician proximity or on hospital credentialing. The network includes and delivers laboratory, radiology, dictation, and other documents to a majority of Indianapolis office practices. The INPC began operation seven years ago and is one of the first and best examples of an LHII.

**I**N RECENT YEARS policymakers have recognized the many potential benefits of health information technology (HIT) and the need to take down the barriers that impede efficient and error-free patient care. The National Committee on Vital and Health Statistics (NCVHS), the U.S. Department of Health and Human Services (HHS), and the eHealth Initiative (eHI) have described the problem in detail and proposed a solution: the community, or local health information infrastructure (LHII), would stitch together the many sources of clinical information within a

community or region, with many potential economic advantages.<sup>1</sup> The Indiana Network for Patient Care (INPC), which has been operating in central Indiana for more than seven years, is an early, working example.<sup>2</sup>

The INPC would not have happened without the National Library of Medicine's (NLM's) high-performance computing and communication initiative, which requested proposals in 1993 for "test bed networks for linking hospitals, clinics, doctor's offices, medical schools, medical libraries, and universities to enable health care providers and researchers

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to share medical data and imagery” and provided the spark and funding that launched the INPC in April 1994. We received subsequent funding from the NLM, the Agency for Healthcare Research and Quality (AHRQ), and the Health Resources and Services Administration (HRSA)—some of it very recently—to continue the clinical expansion of the INPC, and from the National Cancer Institute, the Indiana Genomics Initiative, and the Indiana Twenty-First-Century fund to develop the network’s clinical/biological research capabilities.

Here we describe the current state of the INPC, the allied Regenstrief systems, and the lessons we have learned. We hope that these will be helpful to other communities that are contemplating or embarking on a similar path.

## Background

The INPC includes most of the Regenstrief Medical Record System (RMRS) clinical data from Wishard Health Services, Indiana University (IU) hospitals, and Methodist Hospital (which merged with IU Hospital to become Clarian), dating from 1972, 1989, and 1995, respectively.<sup>3</sup> It began capturing clinical information from Community, St. Vincent, and St. Francis hospitals in 1999, 2000, and 2002, respectively. By 2004 all INPC institutions had committed to providing radiology reports, discharge summaries, operative notes, pathology reports, medication records, and EKG reports as their minimum contribution to the INPC. The five participating systems operate fifteen hospitals and more than a hundred clinics and day surgery facilities, distributed throughout Indianapolis and the surrounding counties. Together they generate 165,878 inpatient admissions and 450,000 emergency room (ER) and 2.7 million outpatient visits per year.

The Marion County Health Department (MCHD) and the Indiana State Department of Health (ISDH) also contribute data: childhood immunization information and public health laboratory results for clinical use and tumor registry data for deidentified research use. Indiana Medicaid has agreed to include much of its administrative data (including prescription records) in the INPC, and RxHub is now de-

livering medication usage history for INPC patients seeking care in Indianapolis ERs.<sup>4</sup> The INPC does not yet gather clinical data from office practices except for a few large group practices closely tied to hospital systems.

The INPC repository now carries 660 million discrete observations; 14.5 million text reports; 45 million radiology images; and 450,000 EKG tracings. These are now growing at the respective rates of 88 million, 2 million, 25 million, and 80,000 per year. Obviously, a greater share of these total data come from the two institutions that have maintained records in the RMRS the longest.

## Clinical Uses Of The Community Database

■ **Access to a patient’s full INPC medical record.** The INPC has developed a communitywide clinical repository, which is organized by patient. The medical record data are segregated into separate files by institutional source, but the data about one patient from many institutions can be viewed as a single virtual medical record, and clinicians can review a patient’s record in a variety of video screens and hard-copy formats.<sup>5</sup>

Because the INPC pool of patients is so large and inclusive, rules are applied that go beyond Health Insurance Portability and Accountability Act (HIPAA) requirements and constrain clinicians’ access to a stingy subset of the total INPC population at any given point in time.

We based our first rule on “proximity” between patient and provider. The INPC knows when a patient has checked into a given facility, because it receives all check-in messages. It uses that information to give physicians working within each facility access to the INPC records of patients who are also there. We have been using this proximity-based approach in Indianapolis ERs for years. We are now implementing the same approach for physicians and patients in a given hospital.

We based our second rule on institutional privileging. This rule allows providers who have staff privileges at two or more INPC institutions to access the INPC data from all of

their institutions at once, so they can look at a patient's data as one record. In the combined view, individual results are footnoted with their institutional source to clarify the data's origin.<sup>6</sup> Physicians already have the right to look at the medical record data in each hospital by virtue of their staff privileges; the INPC makes access easier and the data more digestible. This access rule has been implemented for all medical staff and residents who have privileges at both Wishard and Clarian hospitals and will be deployed more widely in the coming year.

■ **Report delivery services.** A second clinical service is report delivery from INPC data sources (for example, laboratories and dictation services) to office clinicians whose names are tied to the report as author, orderer, or a "copy-to." This service is provided by a Regenstrief system called DOCS4DOCS (D4D). D4D takes the same Health Level Seven (HL7) report messages that flow to the federated INPC repository and stores them in its own database, organized by practice. This system alerts the practice to the arrival of new reports, generates reports for distribution to providers or chart filing, and allows providers to review reports directly at any time. D4D illustrates yet another rule for constraining access: Each practice can only access reports delivered to clinicians from that practice. D4D delivers electronic copies of discharge summaries, operative notes, EKGs, and radiology reports from the five major Indianapolis hospitals, but more sources are being added.

D4D gives the receiving practices fine-grained control over which reports they get—for example, inpatient versus outpatient, preliminary or final, and report forwarding to other physicians involved in the patient's care. It verifies receipt and notifies source systems about reports that have not been reviewed by the receiving practice. It can also route the original HL7 messages to electronic medical records (EMRs) in office practices.

In 2004, Indianapolis civic leaders created a nonprofit organization, the Indiana Health Information Exchange (IHIE), to support the INPC infrastructure. The IHIE board includes representatives from the mayor's office, Bio-

Crossroads (a life science network of public, private, and university institutions), the Marion County and Indiana State Public Health Departments, the state and county medical societies, the chief executives of each of the major hospital systems, and other community leaders. The IHIE's first charge is to extend the Regenstrief D4D report delivery system to all central Indiana clinical data producers and their clinician "customers."

### Public Health And Research Uses

The INPC serves many masters. It serves public health by scrutinizing all incoming HL7 laboratory messages for results of public health interest and reports them to the state and county health departments.<sup>7</sup> It is building a network to capture chief complaint information in real time from all 140 hospital ERs in Indiana for biosurveillance and outbreak detection. Thirty-six hospitals are now connected; the rest will be connected over the next few years.

The INPC also serves biomedical research. Clinical researchers at the IU School of Medicine have long used the Wishard and Clarian INPC repositories to estimate the number and demographic characteristics of patients with particular diseases for research planning and grant writing. Under institutional review board (IRB)-approved rules, they use the data to verify that study candidates qualify before inviting them into a study and to pull information about side effects and outcomes of patients in active studies. They also use them for epidemiologic studies, the best example of which is the one that discovered the associations between erythromycin and pyloric stenosis among newborns.<sup>8</sup> Our associate dean of research estimates that more than 2,000 of the active human research studies at IU use parts of the INPC repository.

The Shared Pathology Informatics Network (SPIN) project extends the INPC content and functionality, especially for cancer research.<sup>9</sup> It provides tools for searching free text as well as structured data. It can also produce deidentified data sets and perform statistical analyses of them.

## Technology

In the federated repository, each institution's data reside in separate physical files on one computer, but files have the same data structure, share the same terminology dictionary, and operate under the same software system.<sup>10</sup>

Providers identify patients by their chart number from the provider's home institution. When the patient has multiple registration records under different chart numbers within or across institutions, the INPC links these numbers through a deterministic linking algorithm similar to that described by Shaun Grannis and colleagues.<sup>11</sup> Thus, providers with the appropriate privileges can access all INPC records for a given patient by typing in the chart number they know. Of the 4.7 million distinct records in the patient registry, 1.7 million are "duplicates" that are linked within the INPC.

Each institution identifies the observations in the messages it delivers to the INPC by local codes that are idiosyncratic to the source institution. These codes are mapped to a common code system, LOINC, to permit consolidation of data about one patient from many institutions for flowsheets, decision support, and public health and research purposes.<sup>12</sup>

Mapping the local observation codes from each new data producer requires manual effort, ranging from a few person-days for the most widely sold EKG system to six to twelve person-months for a large laboratory service. The mapping of laboratory test codes is the most difficult because of the large numbers (2,000–4,000) of distinct test observations per laboratory and the short and sometimes ambiguous laboratory test names. We use the RELMA mapping tool (freely available) to develop these mappings and to create "synthetic" master files by distilling hundreds of thousands of HL7 messages into one record per local code. Each such record includes the test name, reporting units, normal ranges, and sample values for a given local code.<sup>13</sup> In contrast, radiology systems typically report a smaller number of distinct "tests" (600–1,500), and their test names tend to be long and more completely defining, so the mapping is easier.

The INPC takes what the source systems

deliver: version 2.3 or 2.4 HL7 messages.<sup>14</sup> In 2004, ninety-two source systems from eight different institutions sent us more than eighty-four million HL7 clinical result messages. It also takes radiology images (using the DICOM standard) from two picture archive systems and NCPDP prescription messages from one outpatient pharmacy system. Another source of outpatient pharmacy information, RxHub, also provides prescription reorders but delivers them as HL7 messages.<sup>15</sup>

The above numbers include most of the high-volume diagnostic sources operating in participating systems, but we still have miles to go before reaching our goal of capturing all relevant clinical data. The INPC does not yet capture scanned documents from any institution—one of which produces thirteen million per year—and it obtains nursing documentation from only two of the five systems. Furthermore, it captures very few of the data produced by nonhospital diagnostic service and physicians' offices. So the number of messages will easily increase five- to tenfold when we reach our target of all electronic data for all patients in the Indianapolis metropolitan area. However, a \$20,000 Hewlett-Packard alpha computer can process the current message volume with less than 10 percent of its capacity, so a tenfold increase is not a difficult stretch.

## Agreements And Governance

The Indianapolis collaborative evolved over ten years as new participants and functions were added. The collaborative operates under a mutual contract that adheres to all HIPAA requirements and allows the use of the repository data for prescribed treatment, public health and research, and purposes with oversight by the INPC management committee. The contract includes a HIPAA business associate agreement; it permits research on deidentified data extracts but prohibits research that compares institutions or providers, even if deidentified, unless specifically approved by the involved parties. The Regenstrief Institute is responsible for gathering and standardizing the data and developing and operating the computer systems. The provider institutions

all commit to providing the same minimal set of clinical reports. There were no intrinsic legal barriers to the construction of the INPC.

■ **Centralized versus distributed solutions.** We have adopted a centralized approach to the construction of our LHII. That is, messages from many source systems flow into one centralized facility, where our staff develops preprocessing routines as needed to fully standardize the HL7 messages, maps local observation and report codes to a universal standard, and links multiple patient and physician identifiers for one individual to a standard ID.

The provision of administrative and clinical services from a central site to many remote institutions is nothing new or radical. One large information system vendor, SMS (now part of Siemens), has been doing this for decades. British Columbia provides LHII functions through a centralized prescription (PharmaNet) and laboratory (PathNET) database for all patients and physicians in the province.<sup>16</sup> The eCHN project in Ontario gathers all laboratory, radiology, and other dictated reports from twenty pediatric institutions for use by pediatricians.<sup>17</sup> All of the Canadian projects are centralized systems fed by HL7 and use LOINC codes as their lingua franca for identifying laboratory tests. Great Britain has embarked on an even more ambitious centralized clinical database for its entire population.

The alternative is the distributed approach, adopted by the Santa Barbara County Data Exchange.<sup>18</sup> This group believes that its approach will have cost and acceptability advantages over the centralized approach. However, without an independent data store, the distributed approach is at the mercy of the data retention policies and response times of the source systems, some of which could be too short or too slow. It is not yet known whether this distributed approach is viable, because the “go-live” dates for this project have slipped more than once, and it is only partially live as of this writ-

ing. However, it has considerable promise. The New England Healthcare EDI Network (NEHEN) and PING personally controlled medical record systems are also distributed systems but not yet operating as LHIIs.<sup>19</sup>

## Discussion And Lessons Learned

LHIIs face the challenge of any multiparty network service.<sup>20</sup> To survive, they must reach a critical mass of users. Because the cost of standardizing a given kind of data source is relatively independent of the volume of data produced, new LHIIs must focus their limited resources on the high-volume data producers, to have any hope of reaching critical mass. In most communities, these will be the large hospital systems. The new LHII can also take advantage of existing provider authentication systems and avoid having to develop their own.

Communities that begin to develop LHIIs should remember that there is a natural order to these things. They should start with services such as report delivery, medical record content, and eligibility information that give information and save time, rather than those, such as order entry, that might seem to require the opposite. From this base, they can add more demanding services. Smaller communities should probably look to the dominant hospital system to be the core of their LHIIs. Hospital systems have the capital, the data, and often existing network connections with care providers. Larger communities should start with hospital collaborations.

Different data services require different standardization efforts. On the one hand, report delivery services such as D4D require a relatively small (a few person-weeks) effort per data source, most of which is consumed by standardizing the local provider codes used to identify report recipients. This effort will shrink further when the National Provider Identifier (NPI) arrives in 2008 and replaces the local provider codes in report messages.<sup>21</sup>

**“If LHIIs’ primary purpose becomes cost control, they will likely fail as did the community health information networks of the 1990s.”**

The standardization effort required to support repository services, such as crossinstitutional flow sheets, decision support, quality assurance, public health reporting, and biomedical research, requires standardization of the report content down to the patient identifier, report/test/measurement identifier, and units of measure. Consequently, LHIIIs that invest in such intensive standardization should try to accommodate multiple missions, such as research and clinical/public health, to spread the cost over many purposes.

Closer attention to the specifications in the HL7 standard by report producers could reduce this standardization effort. For example, HL7 structured observation message standard provides a separate slot for recording the value, the units of measure, the abnormal flag, and the normal range and anticipates that data producers will put each of these components in its designated slot. Yet some source systems jam multiple components into one slot; that is, they store “5.0 mcg/ml High .07–1.5, Acme Lab 2235 Sendout Road, Persimmon, Ohio” in the value slot and leave the other slots empty, when they should have stored “5” in the value slot, “mcg/ml” in the unit slot, and so on. Some sources commit an even worse sin by jamming the test name and values for many tests into one slot. This defeats the purpose of having a structured message and prevents the use of these data of decision support, performance measurement, and statistical purposes.

We don't need new messaging standards to create an LHII—we need better adherence to the ones we have—and perhaps government incentives directed at the report producers to eliminate the practices described above. Incentives directed at data sources to produce good messages could do more to accelerate EMR use than any amount of incentives on the office practices that will receive these messages.

LHIIIs can be expected to improve efficiency and reduce cost growth. However, if their primary purpose becomes cost control, they will likely fail as did the community health information networks (CHINs) of the 1990s.<sup>22</sup> In the long run, the cost problem is driven by the continued development of costly

life-saving technologies and is not amenable to purely technical solutions.

**T**HE SERVICES that the INPC provides are only examples of what the ultimate LHII could provide—for example, individual patient medical records, e-prescribing, clinical reminders, eligibility information, and medical literature/knowledge access. Centralized LHIIIs that capture and standardize major portions of a community's clinical record information could also become the low-cost EMR for small office practices, because disaster recovery, backup, security control, standardization, and system management could all be done once at the central facilities rather than repeatedly at separate offices.

We in Indianapolis have succeeded in implementing a communitywide health information infrastructure that includes most of the elements of an LHII. The system carries medical record information from all of the major Indianapolis hospitals and serves clinical, research, and public health functions. We have shown that LHIIIs are feasible and their services popular. To paraphrase Sir Elton John, we (institutional and individual care providers) are “taking down the barriers and loving what we find” (“Breaking Down Barriers,” 1981).

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## NOTES

1. National Committee on Vital and Health Statistics, *Information for Health—A Strategy for Building the National Health Information Infrastructure* (Washington: U.S. Department of Health and Human Services, 2001); Markle Foundation/Robert Wood Johnson Foundation, *Connecting Americans to Their Healthcare*, July 2004, [www.connectingforhealth.org/resources/wg\\_eis\\_final\\_report\\_0704.pdf](http://www.connectingforhealth.org/resources/wg_eis_final_report_0704.pdf) (26 July 2005); and J. Walker et al., “The Value of Health Care Information Exchange and Interoperability,” *Health Affairs*, 19 January 2005, [content.healthaffairs.org/cgi/content/abstract/hlthaff.w5.10](http://content.healthaffairs.org/cgi/content/abstract/hlthaff.w5.10) (31 May 2005).
2. See J.M. Overhage et al., “A Randomized Controlled Trial of Clinical Information Shared from Another Institution,” *Annals of Emergency Medicine* 39, no. 1 (2002): 14–23; and J.M. Overhage, W.M. Tierney, and C.J. McDonald, “Design and Implementation of the Indianapolis Network for Patient Care and Research,” *Bulletin of the Medical Library Association* 83, no. 1 (1995): 48–56. President George W. Bush commented that “the reason why Indianapolis is farther down the road [is that]...hospitals can talk to hospitals, which hasn't happened in many communities.” G.W. Bush, “Transforming Health Care for Americans with Health Information Technology,” 27 May 2004, [www.whitehouse.gov/news/releases/2004/05/20040527-5.html](http://www.whitehouse.gov/news/releases/2004/05/20040527-5.html) (1 May 2005).
3. C.J. McDonald, et al., “The Regenstrief Medical Record System: A Quarter Century Experience,” *International Journal of Medical Informatics* 54, no. 3 (1999): 225–253.
4. See the RxHub home page, [www.RxHub.com](http://www.RxHub.com).
5. See Supplemental Exhibits 1, 2, and 3 at [content.healthaffairs.org/cgi/content/full/24/5/1214/DC1](http://content.healthaffairs.org/cgi/content/full/24/5/1214/DC1).
6. See Supplemental Exhibit 1; *ibid*.
7. See J.M. Overhage, J. Suico, and C.J. McDonald, “Electronic Laboratory Reporting: Barriers, Solutions, and Findings,” *Journal of Public Health Management and Practice* 7, no. 6 (2001): 60–66.
8. B.E. Mahon, M.B. Rosenman, and M.B. Kleiman, “Maternal and Infant Use of Erythromycin and Other Macrolide Antibiotics as Risk Factors for Infantile Hypertrophic Pyloric Stenosis,” *Journal of Pediatrics* 139, no. 3 (2001): 380–384.
9. C.J. McDonald et al., “SPIN Query Tools for De-Identified Research on a Humongous Database,” JAMIA (Symposium supp.): Proceedings of the American Informatics Association Annual Symposium, Fall 2005 (forthcoming).
10. See online Supplemental Exhibit 4 (Note 5).
11. S.J. Grannis, J.M. Overhage, and C.J. McDonald, “Analysis of Identifier Performance using a Deterministic Linkage Algorithm,” *Journal of the American Medical Informatics Association (Symposium Supplement), Proceedings of the American Medical Informatics Association Annual Symposium* (Fall 2002): 305–309.
12. C.J. McDonald et al., “LOINC, A Universal Standard for Identifying Laboratory Observations: A Five-Year Update,” *Clinical Chemistry* 49, no. 4 (2003): 624–633.
13. The Regenstrief LOINC Mapping Assistant (RELMA) can be obtained from [www.loinc.org/relma/download/relma](http://www.loinc.org/relma/download/relma) (2 May 2005).
14. For more information, see HL7, “About HL7,” [www.hl7.org/about](http://www.hl7.org/about) (21 June 2005).
15. National Electrical Manufacturers Association, *Digital Imaging and Communication in Medicine: The ARC-NEMA DICOM Standard* (Rosslyn, Va.: NEMA, 2004); and “NCPDP—The National Council of Prescription Drug Programs,” [www.hl7.org/standards/ncpdp.htm](http://www.hl7.org/standards/ncpdp.htm) (2 May 2005).
16. Government of British Columbia, Ministry of Health Services, “PharmaNet,” [www.healthservices.gov.bc.ca/pharme/pharmanet/netindex.html](http://www.healthservices.gov.bc.ca/pharme/pharmanet/netindex.html) (1 May 2005); and British Columbia Biomedical Laboratories and MDS Metro Laboratory Services, “PathNet,” [www.pathnet.ca/about.php](http://www.pathnet.ca/about.php) (1 May 2005).
17. Child Health Network, “eCHN (Electronic Child Health Network),” [www.echn.ca](http://www.echn.ca) (1 May 2005).
18. CareScience, “Santa Barbara County Care Data Exchange,” 2003, [www.carescience.com/healthcare\\_providers/cde/care\\_data\\_exchange\\_santabarbara\\_cde.shtml](http://www.carescience.com/healthcare_providers/cde/care_data_exchange_santabarbara_cde.shtml) (1 June 2005).
19. J.P. Glaser, G. DeBor, and L. Stuntz, “The New England Healthcare EDI Network,” *Journal of Healthcare Informatics Management* 17, no. 4 (2003): 42–50; and W.W. Simons, K.D. Mandl, and I.S. Kohane, “The PING Personally Controlled Electronic Medical Record System: Technical Architecture,” *Journal of the American Medical Informatics Association* 12, no. 1 (2005): 47–54.
20. N. Economides and C. Himmelberg, “Critical Mass and Network Evolution in Telecommunications,” in *Toward a Competitive Telecommunications Industry, Selected Papers from the 1994 Telecommunications Policy Research Conference*, ed. G.W. Brock (Mahwah, N.J.: Lawrence Erlbaum, 1995).
21. “HIPAA Administrative Simplification: Standard Unique Health Identifier for Health Care Providers; Final Rule,” *Federal Register* 69, no. 15 (2004): 3433.
22. John A. Hartford Foundation, *Benton International, Community Health Management Information System: Functional Specifications* (New York: Hartford Foundation, 1991).