Islands of Information: Linking Clinical Data

J. Marc Overhage

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Islands of Information: Linking Clinical Data

J. Marc Overhage, MD, PhD
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Regenstrief Institute, Inc.
Indiana University School of Medicine

Current Status of Medical Records

Decade of Health Information Technology

Inform Clinical Practice
- Strategy 1: Incentivize EHR adoption
- Strategy 2: Reduce risk of EHR investment
- Strategy 3: Promote EHR diffusion in rural and underserved areas

Personalize Care
- Strategy 1: Encourage use of Personal Health Records
- Strategy 2: Enhance informed consumer choice
- Strategy 3: Promote use of telehealth systems

Interconnect Clinicians
- Strategy 1: Foster regional collaborations
- Strategy 2: Develop a national health information network
- Strategy 3: Coordinate federal health information systems

Improve Population Health
- Strategy 1: Unify public health surveillance architectures.
- Strategy 2: Streamline quality and health status monitoring
- Strategy 3: Accelerate research and dissemination of evidence

Registration Cross-over

<table>
<thead>
<tr>
<th>Hospital systems</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40%</td>
</tr>
<tr>
<td>2</td>
<td>39%</td>
</tr>
<tr>
<td>3</td>
<td>18%</td>
</tr>
<tr>
<td>4</td>
<td>3%</td>
</tr>
<tr>
<td>5</td>
<td>&lt;1%</td>
</tr>
</tbody>
</table>

Emergency Department Cross-over

<table>
<thead>
<tr>
<th>Hospital System</th>
<th>Number of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hosp A</td>
<td>25000</td>
</tr>
<tr>
<td>Hosp B</td>
<td>20000</td>
</tr>
<tr>
<td>Hosp C</td>
<td>15000</td>
</tr>
<tr>
<td>Hosp D</td>
<td>10000</td>
</tr>
<tr>
<td>Hosp E</td>
<td>5000</td>
</tr>
</tbody>
</table>

*More than one visit
The Indiana Network for Patient Care (INPC)

An operational community wide electronic medical record

Indianapolis, Indiana

- 1.5 million population base
- 12th largest city in U.S.A.
- Home to Indiana’s only medical school
- State Department of Health
- Referral center for entire state (7 million)

Initial RMRS Aims

- Eliminate the logistic problems associated with the paper record
- Standardize the care process. Deliver information in a more organized and useful way. Actively process this record and provide decision support to clinicians.
- Analyze and understand the data to improve the health of populations

INPC Project Goal

Demonstrate the feasibility and benefit of a community wide electronic medical record system in acute care situations.

INPC Project Motto

Resistance is futile!

You will be assimilated
Pilot Project

- Participants
  - Methodist
  - Community East
  - Wishard
- Data - Wishard only
- Outcomes
  - Charges
  - ED visits
  - Admissions

Pilot Emergency Departments

<table>
<thead>
<tr>
<th>Institution</th>
<th>ED Visits</th>
<th>Beds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wishard</td>
<td>100,000</td>
<td>350</td>
</tr>
<tr>
<td>Methodist</td>
<td>90,000</td>
<td>800</td>
</tr>
<tr>
<td>Community</td>
<td>48,000</td>
<td>350</td>
</tr>
</tbody>
</table>

Emergency Dept. Data Flows

- INPC
- Registration Message
- Merged Clinical Abstract
- Merged Result Retrieval
- ED Charge Data

Pilot patient demographics

<table>
<thead>
<tr>
<th>Study ED</th>
<th>Methodist Hospital</th>
<th>Community Hospital</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>Control</td>
<td>Intervention</td>
</tr>
<tr>
<td>Control</td>
<td>10,526</td>
<td>10,094</td>
</tr>
<tr>
<td>Intervention</td>
<td>5,568</td>
<td>5,680</td>
</tr>
<tr>
<td>Patients (%)</td>
<td>32.7 ± 21</td>
<td>32.7 ± 21</td>
</tr>
<tr>
<td>Age years</td>
<td>34.2 ± 22</td>
<td>33.6 ± 22</td>
</tr>
<tr>
<td>Female %</td>
<td>56.9%</td>
<td>56.1%</td>
</tr>
<tr>
<td>Black %</td>
<td>56.4%</td>
<td>56.1%</td>
</tr>
</tbody>
</table>

Pilot ED visit charges

- Community
- Methodist
- Wishard

<table>
<thead>
<tr>
<th>Community</th>
<th>Methodist</th>
<th>Wishard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>400</td>
<td>450</td>
</tr>
<tr>
<td>Intervention</td>
<td>430</td>
<td>500</td>
</tr>
<tr>
<td>Wishard</td>
<td>470</td>
<td>520</td>
</tr>
</tbody>
</table>
Islands of Information: Linking Clinical Data

Clinical INPC functions

- Results retrieval
- Clinical messaging/document delivery
- Data entry
- Reporting
- Clinical decision support
- Public health surveillance
- Medical reference access

Consolidating the Silos

INPC Storage Strategy

- Separate medical record vault per institution
- Each vault in separate physical files
- Standardized data structure – All use same software and observation codes.
- Combine on the fly when needed
- Patient linking

Indiana Network for Patient Care (INPC)

- A local health information infrastructure (LHII)
- We serve as the “Data Switzerland” for the city of Indianapolis and the state
- Up and running for more than 9 years
- Started with a modest goal (Emergency Care)
- Extended by adding projects one step at a time
- Focus on clinical and public health issues, particularly electronic laboratory reporting

INPC – Participants

- Includes 11 hospitals from the 5 major Indianapolis hospital systems (95% of non-office care)
- Includes all four homeless care systems
- Includes county and state public health departments
- Many outpatient practices
- Both major cardiology referral centers
Islands of Information: Linking Clinical Data

Clinical INPC Users
- Almost all med/surg hospital EDs
- Hospital based providers (expanding)
- Ambulatory physicians (approximately 35%)
- Homeless care network
- Public school clinics
- Marion County Health Department
- Indiana State Department of Health

INPC Contents
- In the system:
  - 1.3 million patients, 5 million registration "events"
  - 24 million orders
  - 488 million coded results
  - 12 million dictated reports
  - 8.8 million radiology reports
  - 25 million prescriptions
  - 480,000 EKG tracings
  - 45 million radiology images
- Added Per Year:
  - 600,000 ambulatory encounters
  - 50,000 inpatient encounters

Clinical Data Standards
- Current
  - HL7 messages for most as the envelope
  - DICOM messages for images as the envelope
  - LOINC for laboratory results content
  - CPT-4 for procedures content
  - ICD-9 for diagnoses content
  - NDC and RxNorm for medications content
- Evolving
  - Organisms for microbiology content
Patient Linkage

- When data is returned from multiple sites, it will need to be combined and linked.
- For example, if "John Doe" is seen for various aspects of his colon cancer at different institutions, the data must be aggregated.

Linkage Methodologies - Deterministic

- "All-or-None"
- Rules based on exact agreement or disagreement
- Match first on a reliable and discriminating identifier (Such as SSN)
- Verify link using additional parameters (Such as LN, FN)

Linkage Methodologies - Probabilistic

- Use statistical methods to generate frequency ratios, similar to likelihood ratios, for each variable

Agreement Ratio = \frac{\text{frequency of agreement among linked records}}{\text{frequency of agreement among non-linked records}}

Disagreement Ratio = \frac{\text{frequency of disagreement among linked records}}{\text{frequency of disagreement among non-linked records}}

Example: Assume 94.1% of last names agree among true links, and last names randomly agree among non-links with a frequency of 0.1%

Agreement Ratio = \frac{0.941}{0.001} = 941, \log_2(941) = 9.88

Disagreement Ratio = \frac{1-0.941}{1-0.001} = 0.059, \log_2(0.059) = -4.08

Linkage Methodologies

Deterministic
- Rapid implementation
- Simple calculations
- Relies on accurate data
- May not function well with other data sets

Probabilistic
- Complex implementation
- Computationally intensive
- More forgiving of data errors
- Algorithm is customized to data being linked

Global Patient Registry

<table>
<thead>
<tr>
<th>Assigning Authority</th>
<th>Global #</th>
<th>Local Pat #</th>
<th>Patient Name</th>
<th>Birthdate</th>
<th>Sex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital A</td>
<td>99-1</td>
<td>231456</td>
<td>Sinkwell, Ralph J</td>
<td>12-2-59</td>
<td>M</td>
</tr>
<tr>
<td>Hospital B</td>
<td>123-0</td>
<td>A47239</td>
<td>Sinkwell, RJ</td>
<td>2-12-59</td>
<td>M</td>
</tr>
<tr>
<td>Hospital A</td>
<td>99-1</td>
<td>1032115</td>
<td>Sinkwell, Ralph</td>
<td>12-2-59</td>
<td>M</td>
</tr>
<tr>
<td>Hospital C</td>
<td>101-0</td>
<td>A3276</td>
<td>Fredrick, Alice</td>
<td>4-14-78</td>
<td>F</td>
</tr>
<tr>
<td>Hospital A</td>
<td>101-0</td>
<td>2314590</td>
<td>Fredrick, Alyce</td>
<td>4-14-78</td>
<td>F</td>
</tr>
</tbody>
</table>
INPC - Confidentiality

- While numerous measures in place to protect confidentiality of patient's data, the provider has to know who the patient is.
  - Secure physical network
  - Encryption
  - Authentication
  - Agreements
  - Device controls

Participants' Agreement

- How can participants share health data to treat patients?
- Who may have access to PHI for treatment purposes?
- What information is to be stored on the network?
- How may the PHI be used for research purposes?
- What are other considerations?
  - Equipment
  - Consistency of data
  - Other uses of information
  - Indemnification
  - Governance
  - Disposition of information upon termination
  - Security

NHII – A National Database
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INPC Data Access

- Select a patient via:
  - INPC Data Access
  - Electronic patient records to display for this patient
Video Records

- Implement video-based teleconferencing between health providers and patients in a nursing facility
- Measure impact on health outcomes
Winston Niles Rumfoord had run his private space ship right into the heart of an uncharted chrono-syn-clastic infundibulum two days out of Mars. Only his dog had been along. Now Winston Niles Rumfoord and his dog Kazak existed as wave phenomena -- apparently pulsing in a distorted spiral with its origin in the Sun and its terminal in Betelgeuse.

**INFUNDIBULUM**

- A funnel-shaped cavity.
- It's the Latin word for a funnel, derived from infundere, "to pour", plus the ending -bulum which formed the names of instruments. In English, it turns up in various anatomical contexts for something funnel-shaped. For example, in the human body it describes the outermost section of the fallopian tubes, a structure in the cochlea of the ear, and a formation in the brain close to the pituitary, among others.
- Science-fiction fans may have come across the splendid phrase chronosynclastic infundibulum that was invented by Kurt Vonnegut in *The Sirens of Titan*, which he explained, perhaps less than helpfully, as being "those places ... where all the different kinds of truths fit together".

**Data reuse**

- Clinical care
  - Emergency room
  - Primary care
  - Inpatient
- Public health (state and local HD)
  - Immunization registry
  - Reportable conditions
  - Surveillance
- Health services research
- Clinical research
- Accreditation reports
Islands of Information: Linking Clinical Data

The "Killer App" – Reusable Data

Patient data

Applications & tools

Increasingly structured clinical data

- Report other laboratories
- Nonhospital labs
- Pharmacists
- Physicians

- Results delivery
- E-mail support
- Electronic transmission
- Public health lab reporting
- Public health screening

Research

- Clinical data screening & management

Admin functions

- Credentialing
- Claims clearing
- Eligibility/referrals/pre-certification

Applications & tools

- Translation
- Claims clearing
- Shigella/thyroid dysfunction verification

Reportable condition processor

Inbound HL7

Potentially Reportable

Abnormal flag

Orgasmic name in Dwyer II Value above threshold

Realtime

Compare to Dwyer I

Reportable Condition

Databases

Reportable Conditions

Daily batch

E-mail

To Public Health

Print

To Infection Control

Public Health Outcomes

- Reliable
  - Real time delivery
  - 100% received (for participants)
- Reporting completeness (capture/recapture)
  - Greatly increased case reporting
- Reporting timeliness (versus result date)
  - 8.4±15.4 days faster than HD
  - 1.4±2.0 days faster than hospital

Shigella Outbreak: Timeline

Public Health Outcomes

Indianapolis Electrolytes, Rotavirus, and RSV

The sales of OTC Electrolytes are a result of two outbreaks: RSV (in gold) and Rotavirus (in pink)

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Islands of Information: Linking Clinical Data

October 2004

2004 © Regenstrief Institute, Inc.
1 year RCT done!

- 80% intervention/20% control
- Intervention
  - Printed abstract
  - On-line access for 24 hours
- Additional covariates

Tentative Results

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Intervention</th>
<th>Mean Charge</th>
<th>Charge Saving</th>
<th>95% CI</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>All visits w/o covariates</td>
<td>$572.93</td>
<td>$563.23</td>
<td>-9.70</td>
<td>-19.01 to -0.40</td>
<td>0.041</td>
<td></td>
</tr>
<tr>
<td>All visits w/ covariate</td>
<td>$571.10</td>
<td>$561.55</td>
<td>-9.55</td>
<td>-18.49 to -0.62</td>
<td>0.036</td>
<td></td>
</tr>
</tbody>
</table>

Indiana Health Information Exchange

- Founded in 1999 by Indiana Health Information Exchange Corporation
- High-level clinical messaging network
- Affiliated with IU School of Medicine
- $12M annual budget
- Standards: HL7, LOINC

Regenstrief Institute

- Founded in 1969 by Sam Regenstrief
- Affiliated with IU School of Medicine
- $12M annual budget
- Pioneers in medical informatics
  - Standards: HL7, LOINC
  - EMRs: RMRS, INPC

CFHC Model

<table>
<thead>
<tr>
<th></th>
<th>Large</th>
<th>Medium</th>
<th>Small</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costs*</td>
<td>$1,000,000</td>
<td>$500,000</td>
<td>$100,000</td>
</tr>
<tr>
<td>Benefits</td>
<td>$750,000</td>
<td>$375,000</td>
<td>$75,000</td>
</tr>
<tr>
<td>Net</td>
<td>$250,000</td>
<td>$125,000</td>
<td>$25,000</td>
</tr>
</tbody>
</table>

CHCF Model

<table>
<thead>
<tr>
<th></th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costs*</td>
<td>$800,000</td>
<td>$400,000</td>
<td>$80,000</td>
</tr>
<tr>
<td>Benefits</td>
<td>$500,000</td>
<td>$250,000</td>
<td>$50,000</td>
</tr>
<tr>
<td>Net</td>
<td>$300,000</td>
<td>$150,000</td>
<td>$30,000</td>
</tr>
</tbody>
</table>
Founding Members

- Hospital systems
  - Clarian Health Partners
  - St. Francis Hospital and Health System
  - St. Vincent Health Care
  - Wishard Health Services
  - Community Hospital of Indiana
- Government
  - City of Indianapolis
- Public Health
  - Marion County Health Department
- Research
  - IU School of Medicine
  - Regenstrief Institute
- Medical societies
  - Indianapolis Medical Society
  - Indiana State Medical Association
- Economic development
  - BioCrossroads / Central Indiana Corporate Partnership

Acknowledgement

- National Library of Medicine
- Agency for Healthcare Quality and Research
- National Cancer Institute
- Regenstrief Foundation
- Eli Lilly and Company INGEN grant
- BioCrossroads

Three Hypothetical Communities Were Modeled

<table>
<thead>
<tr>
<th>Community Size</th>
<th>Constituent Type</th>
<th>Participation in Community</th>
<th>Physician Usage Adoption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large</td>
<td>Major hospital</td>
<td>15%</td>
<td>35%</td>
</tr>
<tr>
<td></td>
<td>Diagnostic imaging center</td>
<td>15%</td>
<td>35%</td>
</tr>
<tr>
<td></td>
<td>Independent laboratory</td>
<td>15%</td>
<td>35%</td>
</tr>
<tr>
<td></td>
<td>PBM</td>
<td>15%</td>
<td>35%</td>
</tr>
<tr>
<td></td>
<td>Major physician groups</td>
<td>15%</td>
<td>35%</td>
</tr>
<tr>
<td></td>
<td>Physicians</td>
<td>15%</td>
<td>35%</td>
</tr>
<tr>
<td>Medium</td>
<td>Major hospital</td>
<td>30%</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td>Diagnostic imaging center</td>
<td>30%</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td>Independent laboratory</td>
<td>30%</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td>PBM</td>
<td>30%</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td>Major physician groups</td>
<td>30%</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td>Physicians</td>
<td>30%</td>
<td>50%</td>
</tr>
<tr>
<td>Small***</td>
<td>Major hospital</td>
<td>45%</td>
<td>65%</td>
</tr>
<tr>
<td></td>
<td>Diagnostic imaging center</td>
<td>45%</td>
<td>65%</td>
</tr>
<tr>
<td></td>
<td>Independent laboratory</td>
<td>45%</td>
<td>65%</td>
</tr>
<tr>
<td></td>
<td>PBM</td>
<td>45%</td>
<td>65%</td>
</tr>
<tr>
<td></td>
<td>Major physician groups</td>
<td>45%</td>
<td>65%</td>
</tr>
<tr>
<td></td>
<td>Physicians</td>
<td>45%</td>
<td>65%</td>
</tr>
</tbody>
</table>

Value Increased w/Community Size & Penetration

- Costs
  - $1,200,000
  - $1,000,000
  - $1,300,000

- Benefits
  - $2,500,000
  - $2,200,000
  - $2,400,000
  - $3,700,000
  - $1,500,000
  - $1,800,000

- Net
  - ($300,000)
  - ($1,200,000)
  - $600,000
  - $2,200,000
  - $1,200,000
  - $2,500,000

J. Marc Overhage, MD, PhD
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Indianapolis, IN 46202
Voice: 317-630-8685
Facsimile: 317-630-6962
E-mail: moverhage@regenstrief.org
Web address: www.regenstrief.org
### Table: Budget Value For Each Constituent: First Mover Disadvantage Existed For All Constituents

<table>
<thead>
<tr>
<th>Constituent</th>
<th>$U.S. annual</th>
<th>Per constituent</th>
<th>Total for all constituents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\text{US},\text{annual}$</td>
<td>$\text{Per constituent}$</td>
<td>$\text{Total for all constituents}$</td>
</tr>
<tr>
<td></td>
<td>$\text{Value}$</td>
<td>$\text{Number of}$</td>
<td>$\text{Total}$</td>
</tr>
<tr>
<td></td>
<td>$\text{benefits}$</td>
<td>$\text{constituent}$</td>
<td>$\text{constituents}$</td>
</tr>
<tr>
<td></td>
<td>$\text{of}$</td>
<td>$\text{of}$</td>
<td>$\text{of}$</td>
</tr>
<tr>
<td></td>
<td>$\text{providing}$</td>
<td>$\text{constituent}$</td>
<td>$\text{constituents}$</td>
</tr>
<tr>
<td></td>
<td>$\text{Net}$</td>
<td>$\text{Net}$</td>
<td>$\text{Net}$</td>
</tr>
<tr>
<td>$\text{Costs}$</td>
<td>$\text{Total}$</td>
<td>$\text{Total}$</td>
<td>$\text{Total}$</td>
</tr>
</tbody>
</table>

| Hospital | $100,000 | 500 | 0 | 7 | $4,500,000 | $1,250,000 |
| Imaging center | $150,000 | 50 | 0 | 4 | $3,000,000 | $1,400,000 |
| Laboratory | $110,000 | 50 | 0 | 2 | $1,100,000 | $440,000 |
| Physician group | $120,000 | 50 | 0 | 3 | $3,000,000 | $1,100,000 |
| Other physicians | $40 | 0 | 0 | 1 | $70,000 | $600,000 |
| PBM | $0 | 0 | 0 | 3 | $330,000 | $0 |

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