High Performance Computing and the Next Generation of Novel Applications

John D. Halamka MD
October 18, 2010
Agenda

• Update on High Performance Computing at Harvard Medical School
• The Stimulus for Healthcare IT (HITECH), Healthcare Reform, and the innovations it will bring
• Innovations in data mining
• Innovations in social networking for research
• Paying for and sustaining our infrastructure and applications
About the Longwood Medical Area

- 213 Acres, 37,000 employees, 15,000 students
- 91% of LMA employees work for healthcare and research institutions (BIDMC, BWH, CHB, DFCI, HMS/HSDM, HSPH, IDI, JDC, and Merck).
- 21 institutions
- 2.15 million in- and outpatient visits
- Forty-seven percent of all hospital-based outpatient clinical visits, and fifty-one percent of all inpatient admissions in Boston
- Forty-seven percent of all staffed beds in Boston
- 14,000 births in the LMA
HMS Affiliated Research – Longwood

- Four of the top five Independent Hospital recipients of NIH funding nationwide
- Massachusetts was the number two state recipient of National Institutes of Health (NIH) funding
- Boston is ranked as the number one city in the nation for NIH support
- If the LMA alone were ranked as a state, it would be number eight, after North Carolina, and before Washington.
- National Institutes of Health (NIH) awards more than doubled for the LMA institutions from $398 million to $927 million over the decade between FY 1995 and FY 2005
What makes Biomed HPC Different?

• Larger problem space
  ◦ Whole Genome processing
  ◦ Image Processing
  ◦ Simulations
  ◦ Matlab, R, SAS, etc
  ◦ Everything Else (c++, python, fortran!)

• Bursty Usage
  ◦ Processing power is not always the bottleneck – i/o is key
  ◦ Much work is done in parallel
Biomed HPC Differences (cont.)

• Researchers
  ◦ Funding challenges
  ◦ Grant funding limitations and requirements
  ◦ Everyone is a CIO :-) 

• Systems Diversity
  ◦ Plethora of small clusters
  ◦ General lack of centralization
  ◦ White boxes to blue genes
About HPC @ HMS

• Today: Orchestra Phase I
  ◦ Modest shared cluster
  ◦ 1000 processor cores
  ◦ 600TB attached NAS storage
  ◦ Interconnect: Gigabit Ethernet
  ◦ Subsidized user contribution model
About HPC @ HMS (cont.)

• This Winter: Orchestra Phase II
  ◦ $3.7 Million NIH S10 ARRA Award
    • Will support 30 existing NIH researchers
  ◦ 6,000 processor cores
  ◦ Petabyte of storage
  ◦ 10g Ethernet
  ◦ High Performance Scratch Space
  ◦ Small, integrated GPU cluster
  ◦ Modest SMP options (24 cores)
Shared Capacity @ HMS

• Critical to the success of the shared infrastructure model
  ◦ ½ the nodes have been contributed because of shared usage models
  ◦ Contributors get guaranteed access to their nodes but others can use them when they were idle
  ◦ NOTE: This approach would fail in many other disciplines

• LSF used for queue management
  • Time limited queues
  • All and shared queues
Storage Needs and Architecture

- 70% annual growth in storage with an accelerating growth rate
  - Driven largely by next generation sequence analysis and high resolution microscopy
- Implemented Isilon Storage Arrays
  - 2 600TB clusters mirrored in different facilities
  - 6 weeks of checkpoints (daily for last week)
  - Uses NFS to the cluster and CIFS to the desktop
How do we guide our research IT?

- Setup a research advisory council consisting of faculty from each of the major departments
- Create an annual strategic plan and vet it internally and with our advisers
- Bring directors and managers together regularly to review plans and coordinate operations and upgrades
- Create a climate of flexibility and adaptability to the ever-changing needs of research IT
Key Lessons

• Pilot first – prove the model and grow over time

• You can’t please everyone with centralized services but you can meet the majority of needs if you try

• Bring the research community on as your advisers and let them help you come up with the solutions

• Subsidize where you can and do cost recovery where it makes sense

• Research IT demands more flexibility than corporate infrastructure but the uptime requirements are not as stringent
Meaningful Use Data Exchanges

Core Set

1. Provide patients an electronic copy of their ambulatory, ED or inpatient summary of care record
2. Transmit prescriptions
3. Capability to exchange key clinical information among care providers and patient authorized entities
4. Report clinical quality measures

Menu Set

5. Incorporate clinical lab tests results into EHRs as structured data
6. Provide summary of care record for patients referred or transition to another provider or setting
7. Capability to submit data to immunization registries, provide syndromic
A Network of Networks Approach

- = Ready to Connect
- = Minor Improvements Needed to Connect
- = Has EHR, Needs HIE Interface
- = No EHR, Use Push Portal
- = 2nd Tier Connectivity Targets

State-wide HIE: Network of Networks

IDA
PCP
HIE
Hosp
IPA
PCP
IDN
PCP
IDN
HIE
Hosp
IDN
HIE

IPA
PCP
PCP
IDN
PCP
Hosp
HIE

HIE/HER Vendors
Payers
Public: State, BPHC, etc...
Independent Pharmacies
Independent Labs

Physical Therapy
Oral Health
Homeopathic
Social Services

Long Term Care
Behavioral Health

Sunday, October 24, 2010
Stage 2 - 2013

Phase 2: Pull – EMPI/RLS, Patients

National Networks

MD
MD

Hospital

MD

IDN

Public Health

MA Statewide Network – “Backbone”

Security: PKI/Identity Services
Quality Data Center

Directory: Provider, Plan, Public Health
Consent Services

Routing
EMPI/RLS
Public Health

Facilitated Services
• Vocabulary Services
• Radiological Image Exchange
• Event Notification
• Routing for Patients
• Personally Controlled Health Record Services

Community Exchanges

MD
MD
MD

Statewide Networks

IPA

Other provider aggregators - CHC

PCP

Specialist

MD
MD
MD

MD
MD
MD

MD
MD
Quality Data Center Project

BIDPO/BIDMC engaged MAeHC to provide a quality data warehouse service to:

- Enable automated extraction and aggregation of selected clinical data from member physicians’ eCW and WebOMR EHR systems
- Develop selected clinical quality measures for BIDPO internal benchmarking, case management, and reporting to commercial and government health plans

BID QDC Service planned go-live: January 1, 2011

- Automated extraction of clinical data from live eCW and WebOMR practices
- Calculation and reporting of measures required by health plans, including BCBSMA (AQC) and CMS (Meaningful Use and PQRI)
- Implemented HHS approved HITSP standard C32 Continuity of Care Document (CCD) as the vehicle for data exchanged (i.e. the payload).
- Using national vocabulary standards
- CCDs are transmitted via the NEHEN Clinical Data Exchange
- Patient Identified data
- Richer data set (includes payer information)
MAeHC QDC System Design

EMR → EHX Server → NEHEN-Clinical Gateway → Internet → NEHEN-Clinical Gateway → WebOMR Server

Transported

XML Snapshot of an encounter, containing visit, diagnosis, problem list, procedure, medication, vaccination and clinical observation request and result information

Received

Consumed

De-identified

Generated

Transported

Roll Ups to Organizational Hierarchies

Generated

Measure reports

Secure portal

BCBSMA CMS Other

MAeHC Quality Data Center (QDC)
Novel Approaches to Data Mining

• Clinical information systems optimized for single patient transactions (hierarchical)

• Clinical data repositories optimized for aggregate queries (relational)
Use Cases

• Identifying cohorts for clinical trials

• Access to human specimens

• Population health surveillance

• Observational studies of genetic variants
• 1989, BIDMC, ClinQuery
  – Search for patients in a clinical database
  – Clinical research, education, administration

• 1998, CHB, DXTractor & Goldminer
  – Complex queries, graphical user interface

• 1999, Partners, RPDR
  – Enterprise rollout
  – Identify cohorts for clinical studies
  – Streamlined IRB workflow
• 2004, Partners, i2b2
  – Informatics for Integrating Biology & the Bedside
  – NIH-Funded National Center for Biomedical Computing at Partners
  – Created open source tools for querying clinical databases
  – Visualization, NLP, data analysis
  – Used at 40+ institutions world-wide
i2b2 - Find Patients

Drag-and-drop query design interface
Demographics Plugin

Analysis of a saved patient set using a “plugin”
Two Patient List Plugin

Compare multiple patient sets
Timeline Plugin

An example of visualization of patient data
Debugging Tools

View all client-server i2b2 communication
SHRINE Prototype (2008)

Shared Health Research Information Network

• Goals
  – Query three i2b2 databases (4 hospitals)
  – Get approval from IRBs and hospital SVPs
  – Six month deadline

• Challenges
  – Protect the Developers (limit scope)
  – Protect the Patients (aggregates only)
  – Protect the Hospitals (mask identity)
Protect the Developers
Limit the Scope

• Start with BIDMC, CHB, and PHS

• Simplify IRB process by limiting to aggregate queries and only seven users

• Limit ontology to demographics and diagnoses (ICD-9)

• Quick and dirty technical architecture
Protect the Patients

Obtain IRB Approval

- No central database
- Only data from 2006
- Patients signed HIPAA notice allowing personal health information to be used for research
- Aggregate counts only; obfuscate by adding small random number; display “<10” for small counts
- Log all queries
- Local PI responsible for data
Protect the Hospitals
Get Approval from Senior Leadership

• Hospitals can back out at any time
• Hospitals not identified by name (e.g., Hospital #1, #2, #3)
• List counts in random order
• Scale counts based on size of hospital
• Reveal all counts simultaneously so the speed doesn’t reveal hospital
Prototype Architecture

Central “aggregator” broadcasts query to local hospital “adaptors”, which return aggregate counts only.
SHRINE Prototype

i2b2 Query & Analysis Tool

Navigate Terms

Find Terms

Query Tool

Query Name:

Group 1
Dates
Occurs > 0x
Exclude
Regional enteritis
Ulcerative colitis

Group 2
Dates
Occurs > 0x
Exclude
Male

Group 3
Dates
Occurs > 0x
Exclude
Neoplasms

one or more of these
AND
none of these
AND
one or more of these

Run Query
New Query
3 Groups

Previous Queries

Query Status

Executing query...
Elapsed time (seconds): 14.0
Query Finished...
Matching patients (hospital 1): 332 (+/-3)
Matching patients (hospital 2): 16 (+/-3)
Matching patients (hospital 3): 151 (+/-3)

Noninf-e-Female@16:39:03
Nonin-Femal-Neopl@16:39:11
Circulatory sys@16:39:18
Circulatory sys@17:01:03
Circula-Events @17:04:11
Demographics@17:04:21
10-19 years old@17:04:39
Albanian@02:31:25
The Sip vs Deep Drink

• The “Sip”
  – Use SHRINE to obtain aggregate counts
  – Discover where patients are located
  – Minimal concern from IRB and institutions

• “Deep Drink”
  – Use i2b2 within an institution to obtain detailed data about individual patients
  – Institutions control local i2b2 implementations
Research Networking

• Why not Google/Facebook/LinkedIn?
  – Need targeted search to find scientists based on expertise, activities, resources, institution, geographic region
  – A more complete profile can be formed by aggregating or linking to multiple data sources
  – Trust in data quality is gained through provenance (e.g., data provided by an institution is expected to be relatively accurate)
  – Network analysis and visualization can reveal new connections and show changes over time

• Why is it important to science?
  – Locating collaborators with particular expertise, skills, or resources
  – Helping students or junior faculty find mentors
Enable National Networking

• Disambiguation
  – Matching data to the right person

• De-duplication
  – Multiple sources of the same data (e.g., a person with faculty appointments at two institutions)

• Data Privacy
  – Concerns from both institutions and individual researchers

• Data Sharing
  – Vision/commitment from various platforms to share information via standard ontologies and protocols
Active & Passive Networks
Network (John’s Concepts)
Network (John’s Concepts)

- John David Halamka, M.D.

Concepts (129)

Concepts are derived automatically from a person's publications.

- Concept Cloud
- Categories
- Timeline
- Details

Concepts are listed here grouped according to their "semantic" categories. Within each category, up to ten concepts are shown, in decreasing order of relevance.

- Activities & Behaviors
  - Computer Security
  - Regional Medical Programs
- Diffusion of Innovation
- Information Management
- Computer Communication Networks
- Medical Records
- Regional Health Planning
- Community Networks
- Information Systems
- Systems Integration

- Anatomy
  - Spermatozoa

- Chemicals & Drugs
  - Troponin I
  - Methyl Methanesulfonate

- Organizations
  - Multi-institutional Systems
  - Health Facilities
- Intensive Care Units, Neonatal
- United States Food and Drug Administration
- Societies, Medical
- Academic Medical Centers
- Emergency Service, Hospital
- Public

- Phenomena
  - Diffusion of Innovation
  - Radio Waves
- Miniaturization
- False Positive Reactions
- Electrocadiography

- Physiology
  - Altitude of Health Personnel
  - Attitude to Computers
- Male
- Female

- Procedures
  - Medical Record Linkage
  - Regional Health Planning
- Community Networks
- Information Systems
- Patient Access to Records
- Delivery of Health Care, Integrated
- Biomedical Technology
- Community Health Planning
- Informed Consent
- Organizational Case Studies

- Co-Authors
  - Kohane, Isaac
  - Mandl, Kenneth
  - Rind, David
  - Safran, Charles
  - Stair, Thomas
  - See all (13) people

- Similar People
  - Middleton, Blackford
  - Safran, Charles
  - Kohane, Isaac
  - Mandl, Kenneth
  - Bergeron, Bryan
  - See all (60) people

- Same Department
  - Burstein, Jonathan
  - Corrigan, Kelly
  - Edlow, Jonathan
  - McGillicuddy, Daniel
  - Salhanick, Steven
  - Search for all (756) people

- Physical Neighbors
  - Arentz, H.
  - Jeon, Andrew
  - Spellman, Mitchell

Sunday, October 24, 2010
## Network (John’s Concepts)

The image shows a screenshot of a webpage or application interface titled "Network (John’s Concepts)". The interface appears to be a profile page for John David Halamka, M.D., focusing on his concepts and publications.

### Table: Concepts

<table>
<thead>
<tr>
<th>Name</th>
<th>Number of publications</th>
<th>Most recent publication</th>
<th>Publications by all authors</th>
<th>Concept score</th>
<th>Why?</th>
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<tbody>
<tr>
<td>Medical Records Systems, Computerize</td>
<td>20</td>
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<td>Why?</td>
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</tbody>
</table>

### Additional Sections

- **Menu**
  - About Profiles
  - Edit My Profile
  - Manage Proxies
  - Logout

- **Halama, J is my...**
  - Collaborator
  - Advisor (Current)
  - Advisor (Past)
  - Advisee (Current)
  - Advisee (Past)

- **My Network**
  - John, Halamka
  - Isaac, Kohane
  - Kenneth, Mandl
  - Shawn, Murphy

- **History**
  - John Halamka
  - George Church
  - Mark Zeidel
  - Ary Goldberger

- **Similar People**
  - Middleton, Blackford
  - Safran, Charles
  - Kohane, Isaac
  - Mandl, Kenneth
  - Bergeron, Bryan

- **Co-Author**
  - Kohane, Isaac
  - Mandl, Kenneth
  - Rind, David
  - Safran, Charles
  - Stair, Thomas

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  - Burstein, Jonathan
  - Corrigan, Kelly
  - Edlow, Jonathan
  - McGillicuddy, Daniel
  - Salhanick, Steven

- **Physical Neighbors**
  - Arez, H.
  - Jeon, Andrew
  - Spellman, Mitchell
Connection (John ↔ Computer Security)

John Halamka to computer security

This is a "connection" page, showing publications John Halamka has written about computer security.

<table>
<thead>
<tr>
<th>John Halamka</th>
<th>11 Matching Publications</th>
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<tbody>
<tr>
<td>35 Total Publications</td>
<td>Connection Strength = 2.704</td>
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   View in: PubMed
   Score: 0.393

   View in: PubMed
   Score: 0.393

   View in: PubMed
   Score: 0.367

   View in: PubMed
   Score: 0.196

6. Halamka JD. Patients should have to opt out of national electronic care records: AGAINST. BMJ. 2006 Jul 1; 333(7557):41-2.
   View in: PubMed
   Score: 0.171

   View in: PubMed
   Score: 0.159
Network (John’s Co-Authors)
Network (John’s Co-Authors)
Network (John’s Similar People)
Connection (John ← Isaac)

---

Connection

Similar Person
This is a "connection" page, showing concepts shared by John Halamka and Isaac Kohane.

<table>
<thead>
<tr>
<th>Concept</th>
<th>Person 1</th>
<th>Person 2</th>
<th>Score</th>
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<td>Medical Records Systems, Computerized</td>
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Connection Strength
The connection strength for similar people is the sum of the scores for each shared concept. A shared concept score is the product of the concept scores for each person. Click any person's concept score value to show details.

Sunday, October 24, 2010
Profile (John Halamka)

John David Halamka, M.D.

Academic Title: Associate Professor of Medicine
Administrative Title: Chief Information Officer
Department: Medicine - Beth Israel Deaconess
Institution: Beth Israel Deaconess Medical Center
Address: Information Systems, 6th Fl
1135 Tremont St
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Fax: 617/754-8015
Email: jhalamka@caregroup.harvard.edu

Narrative

John D. Halamka, MD, MS, is Chief Information Officer of the CareGroup Health System, Chief Information Officer and Dean for Technology at Harvard Medical School, Chairman of the New England Health Electronic Data Interchange Network (NEHEN), CEO of MA-SHARE (the Regional Health Information Organization), Chair of the US Healthcare Information Technology Standards Panel (HTSP), and a practicing Emergency Physician.

Publications

List All | Timeline
5. Halamka JD. Patients should have to opt out of national electronic care records: AGAINST. BMJ. 2006 Jul 1; 333(7557):41-2.
Profile (Computer Security)

Computer Security

Concept Type

"Computer Security" is a descriptor in the National Library of Medicine's controlled vocabulary thesaurus, MeSH (Medical Subject Headings). Descriptors are arranged in a hierarchical structure, which enables searching at various levels of specificity.

MeSH Information

Definition | Details | More General Concepts | Related Concepts | More Specific Concepts

Descriptor ID: D016494
MeSH Number(s): L01.209
N04.452.910.200

Concepts/Terms

- Computer Security
- Compromising of Data
- Computer Hackers
- Computer Viruses
- Computer Worms
- Data Protection
- Data Security
- Information Protection

Publications

Timeline | Most Cited | Most Recent | Earliest

This graph shows the total number of publications written about "Computer Security" by people in Profiles by year, and whether "Computer Security" was a major or minor topic of these publication. In all years combined, a total of 64 publications were written by people in Profiles.

   View in: PubMed
   Citations: 19 times

   View in: PubMed
Sustaining it all

- Institutional Commitment
- Direct and Indirect Grant funding
- Selected chargebacks
- Community Contributions
- Tools and Technology Innovation Funding