Introduction to Biomedical Informatics, Part I

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Medical Imaging Informatics Group
Dept of Radiological Sciences
UCLA School of Medicine
**Objective:** Provide basic and clinical translational scientists with a working understanding of biomedical informatics principles and their applications in biomedical data collection, standardization, representation, and analysis.

<table>
<thead>
<tr>
<th>Intro to Biomedical Informatics</th>
<th>Data Standards &amp; Terminologies</th>
<th>Practical Tools in Informatics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiarize participants with the basic principles of biomedical informatics demonstrated by ongoing projects and services across the CTSI sites.</td>
<td>Describe the use of data standards for representation and exchange of clinical information in the context of electronic health records and clinical decision support.</td>
<td>Provide a demonstration of CTSI-specific applications and resources that facilitate the management and analysis of clinical and experimental data.</td>
</tr>
<tr>
<td>• Introduce the foundational concepts of biomedical informatics and its subfields</td>
<td>• Describe the use of standards for data coding, knowledge representation and exchange of clinical information</td>
<td>• Demonstrate data collection using REDCap</td>
</tr>
<tr>
<td>• Understand the role of informatics in evidence-based medicine</td>
<td>• Discuss the importance of controlled terminologies as a specific class of standards</td>
<td>• Discuss software tools and resources for data collection, extraction and representation, and analysis</td>
</tr>
<tr>
<td>• Distinguish the different types of health information</td>
<td>• Learn about health information system architecture</td>
<td>• Showcase resources available through the CTSI, member campuses, and the UC system</td>
</tr>
</tbody>
</table>
Lecture Outline

• 5/7 Part I: Informatics in healthcare and translational research (D. Bell, 1.5 hrs)
  – Introduce the fundamental concepts of biomedical informatics and its subfields
  – Learn about UCLA CTSI efforts related to this area and whom to contact for expert consultation

• 5/9 Part II: Community-based informatics research (O. Ogunyemi, 1.5 hrs)
  – Summarize the role of informatics in public health and addressing health disparity issues
  – Define disease registries, their implementation and applications, and considerations
  – Discuss development towards a national learning health care system

• 5/14 Part III: Electronic health record systems (R. Jenders, 1.5 hrs)
  – Introduce principles of health information system architecture and design
  – Describe the use of standards for data coding, knowledge representation, and exchange of clinical information

• 5/16 Part IV: Clinical decision support (R. Jenders, 1.5 hrs)
  – Enumerate techniques for clinical decision support (e.g., alerts, infobuttons)
  – Present standards for clinical decision support

• 5/23 Part V: Practical tools in biomedical informatics (W. Hsu/C. Arnold, 3 hrs)
  – Demonstrate data collection using REDCap
  – Discuss software tools and resources for data collection, extraction and representation, and analysis
Module Resources

• Recorded webcast & materials
  – http://www.ctsi.ucla.edu/education/training/webcastmodules

• CTSI virtual home
  – http://www.ctsi.ucla.edu
  – Biomedical Informatics Program
    http://www.ctsi.ucla.edu/about/pages/bip2

• Other resources
  – American Medical Informatics Association
    http://www.amia.org
  – UC BRAID/UC ReX
    http://www.ucbraid.org/informaticsmdashuc-rex.html
  – What is Biomedical and Health Informatics?
    http://skynet.ohsu.edu/~hersh/whatis/
  – National Library of Medicine
    http://www.nlm.nih.gov/
  – UCLA Darling Biomedical Library Workshop Series
    http://uclabiomed.eventbrite.com/
  – UCLA Medical Imaging Informatics Training Program
    http://www.mii.ucla.edu/trainingprogram/
Informatics in healthcare and translational research

Douglas Bell, MD, PhD
Associate Professor in Residence
Leader, Biomedical Informatics Program, CTSI
Division of General Internal Medicine, UCLA School of Medicine
Biomedical Informatics

Definition:

*Biomedical informatics* (BMI) is the interdisciplinary field that studies and pursues the effective uses of biomedical data, information, and knowledge for scientific inquiry, problem solving, and decision making, motivated by efforts to improve human health.

-- American Medical Informatics Association

Corollaries to the Definition

1. BMI develops, studies and applies theories, methods and processes for the generation, storage, retrieval, use, and sharing of biomedical data, information, and knowledge.

2. BMI builds on computing, communication and information sciences and technologies and their application in biomedicine.

3. BMI investigates and supports reasoning, modeling, simulation, experimentation and translation across the spectrum from molecules to populations, dealing with a variety of biological systems, bridging basic and clinical research and practice, and the healthcare enterprise.

4. BMI, recognizing that people are the ultimate users of biomedical information, draws upon the social and behavioral sciences to inform the design and evaluation of technical solutions and the evolution of complex economic, ethical, social, educational, and organizational systems.

Source: American Medical Informatics Association
Subfields of BMI

- Biomedical informatics, methods, technologies, theories
- Bioinformatics imaging
- Informatics
- Clinical informatics
- Public health informatics
- Basic research
- Applied research informatics
  - Molecular and Cellular Processes
  - Tissues and Organs
  - Individuals (Patients)
  - Populations and Society

Source: American Medical Informatics Association
Interdisciplinary Nature of BMI

Biomedical Informatics

- Computer Science (hardware)
- Computer Science (software)
- Cognitive Science & Decision Making
- Management Sciences
- Clinical Sciences
- Basic Biomedical Sciences
- Bioengineering
- Epidemiology And Statistics

Source: American Medical Informatics Association
Motivating Challenges

• Safety
  – Institute of Medicine Study (To Err is Human):
    ~98,000 deaths per year are caused by error in the US (Kohn, 2000)

• Cost (Angrisano et al, 2007)
  – U.S. spends $2.1 trillion on healthcare, annually
  – $436 billion is spent on outpatient care
  – $98 billion is spent on drug costs
  – $91 billion is spent on health administration

• Care Coordination
  – Redundant tests ordered
  – Delayed, inaccurate information transfer at hospital discharge are common and adversely affect patient care (Kripalani, 2007)

• Quality
  – Overuse, underuse, misuse
    • Adults: 55% of recommended care (McGlynn, NEJM 2003)
    • Children: 47% of recommended care (Mangione-Smith, NEJM 2007)
Biomedical informatics in **healthcare**

- Essentially *all* clinical applications of computing are intended to provide decision support
- Biomedical informatics is inherently aimed at enhancing the quality of decisions made by health professionals and patients (*Shortliffe, 2009*)

- **Evidence-based medicine:** The conscientious, explicit, and judicious use of current best evidence in making decisions about the care of individual patients (*Sackett, 2007*)
HIT Tools to Affect Change

• Computerized Provider Order Entry (CPOE)
  – A computer application that enables clinicians to order and process medications, lab tests, clinical procedures and other services electronically.

• Clinical Decision Support (CDS) Systems
  – An electronic system designed to aid in clinical decision making, in which characteristics of individual patients are used to generate patient-specific assessments or recommendations that are presented to clinicians for consideration
## Role of BMI in Health Services

### Donabedian Model

<table>
<thead>
<tr>
<th>Structure</th>
<th>Process</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPOE</td>
<td>Med errors</td>
<td>Mortality</td>
</tr>
<tr>
<td>CDS</td>
<td>Quality measures</td>
<td>QOL</td>
</tr>
<tr>
<td>EHR usability</td>
<td>EHR use</td>
<td>BP control</td>
</tr>
<tr>
<td>User training</td>
<td>User errors</td>
<td>Adverse events</td>
</tr>
</tbody>
</table>
• **Adverse event**
  – An *injury* caused by healthcare intervention, **not**
    due to the underlying condition of the patient

• **Error**
  – Use of a bad plan or
    failure to execute plan properly
Early Evidence: Patient Safety

• 1991: Harvard Medical Practice Study
  – 51 NY hospitals
    → 30,121 medical records
  – 3.7% of admissions had an adverse event
    (14% fatal)
  – 58% errors, 28% negligent
  – Adverse drug events (ADEs) the most common adverse event
Projection

• 33.6 Million hospital admissions
  \[(3.7\% \text{ AEs} \times 13.6\% \text{ fatal} \times 58\% \text{ preventable})\]
  \[= 98,000 \text{ preventable deaths}\]
  \[(2.9\% \text{ AEs} \times 6.6\% \text{ fatal} \times 68\% \text{ preventable})\]
  \[= 44,000 \text{ preventable deaths}\]

• Compare with 1998 deaths from...
  – MVA: 43,458
  – Breast CA: 42,297
  – AIDS: 16,516

[Kohn, 2000]
1995: ADE Prevention Study
- 2 hospitals: prospectively identified med errors
- 6.5 ADEs/100 admissions
  - 1.8 preventable, 4.7 non-preventable
CPOE for ADE Prevention

• Before vs. after CPOE
  – Preventable ADEs 4.7 → 3.9/1000 pt-days (17%)
  – Non-intercepted potential ADEs 6.0 → 1.0 (84%)
  – Non-intercepted serious errors 10.7 → 4.9 (55%)

• ... vs. CPOE after additional refinements:
  – Non-intercepted serious errors → 1.1 (86%)
    • But intercepted
      K+ errors
    initially
    increased
• Inpatient CPOE at U. Penn: [Koppel, JAMA 2005]
  – 22 new types of errors documented in shadowing residents; these occurred frequently; e.g.:
    • One-time orders get entered as standing orders
    • Gap in antibiotics because not renewed
IT System Errors

– Koppel surveyed 95 housestaff about frequency of errors

<table>
<thead>
<tr>
<th>Error Type</th>
<th>Error Frequency During Past 3 Months, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information Errors*</td>
<td></td>
</tr>
<tr>
<td>Used CPOE to determine low dose for infrequently used medications</td>
<td>27.3</td>
</tr>
<tr>
<td>Used CPOE to determine the range of doses for infrequently used medications</td>
<td>18.5</td>
</tr>
<tr>
<td>Delayed for several hours canceling medication because of fragmented CPOE display</td>
<td>48.6</td>
</tr>
<tr>
<td>Observed a gap in antibiotic therapy because of unintended delay in reapproval of antibiotic</td>
<td>16.9</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Human-Machine Interface Flaws†</th>
<th></th>
</tr>
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<tbody>
<tr>
<td>Not able to quickly tell which patients ordering for because of poor CPOE display</td>
<td>45.4</td>
</tr>
<tr>
<td>Been uncertain about patients’ medications because of multiple CPOE displays</td>
<td>28.5</td>
</tr>
<tr>
<td>Delayed ordering because CPOE system down</td>
<td>16.3</td>
</tr>
<tr>
<td>Had difficulty specifying medications and problems ordering off-formulary medications</td>
<td>8.5</td>
</tr>
</tbody>
</table>

Abbreviation: CPOE, computerized physician order entry.

*Generated by fragmentation of data and failure to integrate the hospital’s several computer and information systems.
†A reflection of machine rules that do not correspond to work organization or usual behaviors.
More Major Challenges

• Pediatric ICU CPOE at Pitt:
  • Han, Pediatrics 2005
    - 2.8% mortality in 13 mo. before → 6.6% in 5 mo. after
      • Couldn’t write orders until pt. registered in ICU system
      • Delay in starting antibiotics

• Ordering takes longer (esp. when learning)
  - History of resident revolt at UVa  [Massaro, 1993]
Variance in System Features

- 60 expert-panel recommendations for e-Rx
- 49% implemented among 10 systems

Wang, JAMIA 2005
Certification Programs & Policy

Authorized Testing and Certifications Bodies

The following organizations have been selected as ONC-Authorized Testing and Certification Bodies (ATCBs) for EHR certification:

- **Surescripts LLC** – Arlington, VA  
  *Date of authorization*: December 23, 2010  
  *Scope of authorization*: EHR Modules: E-Prescribing, Privacy and Security

- **ICSA Labs** – Mechanicsburg, PA  
  *Date of authorization*: December 10, 2010  
  *Scope of authorization*: Complete EHR and EHR Modules

- **SLI Global Solutions** – Denver, CO  
  *Date of authorization*: December 10, 2010  
  *Scope of authorization*: Complete EHR and EHR Modules

- **InfoGard Laboratories, Inc.** – San Luis Obispo, CA  
  *Date of authorization*: September 24, 2010  
  *Scope of authorization*: Complete EHR and EHR Modules

Certified Health IT Product List

The online list of certified electronic health record technology is updated as ONC-ATCBs certify new products.

Regulations

- Temporary Certification Program Final Rule [PDF – 305 KB]
- Permanent Certification Program Final Rule [PDF – 442 KB]
• New Jersey E-Prescribe Program, Jan – June 2006
  – 293 prescribers who installed in CY 2005
  – Incentive for use up to $500/qtr

Pevnick, Am J Managed Care 2010
EMR Incentives in ARRA

• Direct Payment Incentives
  – Medicare: Up to $44k/physician over 5 yr if using by 2011, then penalty
    • $15,000 in 2011, then $12,000, $8,000, $4,000 and $2,000
    • Must demonstrate “Meaningful Use” of certified EHR
  – Medicaid: Cover 85% of EHR, up to $63,750 if start 2011

• Regional Extension Centers
  – Direct on-site technical assistance in:
    • Selecting a certified EHR product
    • Achieving effective implementation of the EHR
    • Enhancing workflows to optimally leverage the EHR
    • Complying with applicable integrity, privacy and security requirements

• National Coordinator for Health IT
  – Farzad Mostashari, MD, ScM
“Meaningful Use”

• **2011 Goal**
  – electronically capture in coded format; report health information; use that information to track key clinical conditions
  – 40% of prescriptions, 30% of all orders entered electronically

• **2013 Goal**
  – electronically capture in coded format; report health information; use that information to improve performance and support care processes

• **2015 Goal**
  – electronically capture in coded format; report health information; use that information to improve outcomes
E-Prescribing

EHR Adoption: The Latest

- Percent of non-federal acute care hospitals with adoption of at least a basic EHR system
- Hospital adoption of EHR systems has more than tripled since 2009
- * denotes significant difference from previous year (p < 0.05)

Source: Office of National Coordinator for Health IT, March 2013 brief
Basic EHR adoption requires the EHR system to have at least a basic set of EHR functions, including clinician notes.

n = survey respondents
N = hospitals surveyed

* Estimate does not meet standards of reliability
† Significantly higher than national average
§ Significantly lower than national average

<table>
<thead>
<tr>
<th>State</th>
<th>Basic EHR, %</th>
<th>n(N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>44.4</td>
<td>2836(4539)</td>
</tr>
<tr>
<td>Alabama</td>
<td>29.1§</td>
<td>42(94)</td>
</tr>
<tr>
<td>Alaska</td>
<td>33.2</td>
<td>12(22)</td>
</tr>
<tr>
<td>Arizona</td>
<td>48.7</td>
<td>33(61)</td>
</tr>
<tr>
<td>Arkansas</td>
<td>44.4</td>
<td>48(71)</td>
</tr>
<tr>
<td>California</td>
<td>49.4</td>
<td>187(339)</td>
</tr>
<tr>
<td>Colorado</td>
<td>68.3†</td>
<td>40(72)</td>
</tr>
<tr>
<td>Connecticut</td>
<td>45.7</td>
<td>24(30)</td>
</tr>
<tr>
<td>Delaware</td>
<td>39.4</td>
<td>5(6)</td>
</tr>
<tr>
<td>District of Columbia</td>
<td>28.7</td>
<td>7(10)</td>
</tr>
<tr>
<td>Florida</td>
<td>43.3</td>
<td>93(186)</td>
</tr>
<tr>
<td>Georgia</td>
<td>46.8</td>
<td>67(139)</td>
</tr>
<tr>
<td>Hawaii</td>
<td>51.8</td>
<td>13(21)</td>
</tr>
<tr>
<td>Idaho</td>
<td>52.4</td>
<td>18(39)</td>
</tr>
<tr>
<td>Illinois</td>
<td>48.9†</td>
<td>141(179)</td>
</tr>
<tr>
<td>Indiana</td>
<td>52.0†</td>
<td>73(107)</td>
</tr>
<tr>
<td>Iowa</td>
<td>47.9</td>
<td>73(117)</td>
</tr>
<tr>
<td>Kansas</td>
<td>25.8§</td>
<td>111(125)</td>
</tr>
<tr>
<td>Kentucky</td>
<td>33.8§</td>
<td>61(97)</td>
</tr>
<tr>
<td>Louisiana</td>
<td>36.4</td>
<td>48(107)</td>
</tr>
<tr>
<td>Maine</td>
<td>27.5§</td>
<td>26(36)</td>
</tr>
<tr>
<td>Maryland</td>
<td>54.1†</td>
<td>34(46)</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>57.8†</td>
<td>38(69)</td>
</tr>
<tr>
<td>Michigan</td>
<td>56.4†</td>
<td>80(132)</td>
</tr>
<tr>
<td>Minnesota</td>
<td>58.8†</td>
<td>124(131)</td>
</tr>
<tr>
<td>Mississippi</td>
<td>34.9</td>
<td>41(91)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>State</th>
<th>Basic EHR, %</th>
<th>n(N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missouri</td>
<td>44.9</td>
<td>109(110)</td>
</tr>
<tr>
<td>Montana</td>
<td>29.5§</td>
<td>33(55)</td>
</tr>
<tr>
<td>Nebraska</td>
<td>42.9</td>
<td>53(85)</td>
</tr>
<tr>
<td>Nevada</td>
<td>44.3</td>
<td>11(30)</td>
</tr>
<tr>
<td>New Hampshire</td>
<td>21.1§</td>
<td>14(26)</td>
</tr>
<tr>
<td>New Jersey</td>
<td>42.6</td>
<td>40(63)</td>
</tr>
<tr>
<td>New Mexico</td>
<td>25.5§</td>
<td>21(31)</td>
</tr>
<tr>
<td>New York</td>
<td>43.1</td>
<td>125(177)</td>
</tr>
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<td>North Carolina</td>
<td>44.2</td>
<td>68(110)</td>
</tr>
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<td>North Dakota</td>
<td>49.3</td>
<td>18(42)</td>
</tr>
<tr>
<td>Ohio</td>
<td>52.3†</td>
<td>106(159)</td>
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<td>Oklahoma</td>
<td>32.4§</td>
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<td>34(59)</td>
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<tr>
<td>Pennsylvania</td>
<td>47.1</td>
<td>112(158)</td>
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<tr>
<td>Rhode Island</td>
<td>68.8†</td>
<td>7(11)</td>
</tr>
<tr>
<td>South Carolina</td>
<td>29.6§</td>
<td>31(58)</td>
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<tr>
<td>South Dakota</td>
<td>70.6†</td>
<td>23(51)</td>
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<td>Tennessee</td>
<td>33.3§</td>
<td>49(117)</td>
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<tr>
<td>Texas</td>
<td>34.8§</td>
<td>233(347)</td>
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<tr>
<td>Utah</td>
<td>12.0*</td>
<td>13(43)</td>
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<tr>
<td>Vermont</td>
<td>70.2</td>
<td>7(14)</td>
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<tr>
<td>Virginia</td>
<td>58.2†</td>
<td>44(79)</td>
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<tr>
<td>Washington</td>
<td>38.3</td>
<td>45(86)</td>
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<tr>
<td>West Virginia</td>
<td>51.2</td>
<td>24(49)</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>62.8†</td>
<td>92(122)</td>
</tr>
<tr>
<td>Wyoming</td>
<td>42.2</td>
<td>17(24)</td>
</tr>
</tbody>
</table>

Source: ONC/AHA, AHA Annual Survey Information Technology Supplement
### What Features Are Present?

<table>
<thead>
<tr>
<th>EHR Functions Required</th>
<th>Basic EHR without Clinician Notes</th>
<th>Basic EHR with Clinician Notes</th>
<th>Comprehensive EHR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electronic Clinical Information</strong></td>
<td>★</td>
<td>★</td>
<td>★</td>
</tr>
<tr>
<td>Patient demographics</td>
<td></td>
<td></td>
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<tr>
<td>Physician notes</td>
<td>★</td>
<td></td>
<td>★</td>
</tr>
<tr>
<td>Nursing assessments</td>
<td></td>
<td>★</td>
<td></td>
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<tr>
<td>Problem lists</td>
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<td>★</td>
<td></td>
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<tr>
<td>Medication lists</td>
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<td>★</td>
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<tr>
<td>Discharge summaries</td>
<td></td>
<td>★</td>
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<tr>
<td>Advance directives</td>
<td></td>
<td></td>
<td>★</td>
</tr>
<tr>
<td><strong>Computerized Provider Order Entry</strong></td>
<td></td>
<td></td>
<td>★</td>
</tr>
<tr>
<td>Lab reports</td>
<td></td>
<td></td>
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<tr>
<td>Radiology tests</td>
<td></td>
<td></td>
<td>★</td>
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<tr>
<td>Medications</td>
<td></td>
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<td>★</td>
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<tr>
<td>Consultation requests</td>
<td></td>
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<td>★</td>
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<tr>
<td>Nursing orders</td>
<td></td>
<td></td>
<td>★</td>
</tr>
<tr>
<td><strong>Results Management</strong></td>
<td></td>
<td></td>
<td>★</td>
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<tr>
<td>View lab reports</td>
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<tr>
<td>View radiology reports</td>
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<td>★</td>
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<tr>
<td>View radiology images</td>
<td></td>
<td></td>
<td>★</td>
</tr>
<tr>
<td>View diagnostic test results</td>
<td></td>
<td></td>
<td>★</td>
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<tr>
<td>View diagnostic test images</td>
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<tr>
<td>View consultant report</td>
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<tr>
<td><strong>Decision Support</strong></td>
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<tr>
<td>Clinical guidelines</td>
<td></td>
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<tr>
<td>Clinical reminders</td>
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<tr>
<td>Drug allergy results</td>
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<tr>
<td>Drug-drug interactions</td>
<td></td>
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<td>Drug-lab interactions</td>
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<tr>
<td>Drug dosing support</td>
<td></td>
<td></td>
<td>★</td>
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</tbody>
</table>

Source: Office of National Coordinator for Health IT, March 2013 brief
Growing Use of Each Feature

- **Active Medication Lists**: 2008: 62%, 2012: 87%, Change: 25%
- **Clinical Decision Support Rule**: 2008: 66%, 2012: 87%, Change: 21%
- **Drug Interaction Checks**: 2008: 59%, 2012: 85%, Change: 26%
- **Clinical Summaries**: 2008: 60%, 2012: 81%, Change: 21%
- **Advanced Directives**: 2008: 45%, 2012: 80%, Change: 35%
- **Maintain Problem Lists**: 2008: 44%, 2012: 78%, Change: 34%
- **Computerized Physician Order Entry (CPOE) for Medication Orders**: 2008: 27%, 2012: 72%, Change: 45%

Source: Office of National Coordinator for Health IT, March 2013 brief
## Meaningful Use Measures

<table>
<thead>
<tr>
<th>Meaningful Use Measures</th>
<th>Meaningful Use Objective</th>
<th>2011</th>
<th>2012</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stage 1 Core Measures</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medication allergy lists</td>
<td>Quality, safety, and efficiency</td>
<td>80</td>
<td>94</td>
<td>18%</td>
</tr>
<tr>
<td>Record demographics</td>
<td>Quality, safety, and efficiency</td>
<td>83</td>
<td>93</td>
<td>12%</td>
</tr>
<tr>
<td>Record smoking status</td>
<td>Quality, safety, and efficiency</td>
<td>72</td>
<td>92</td>
<td>28%</td>
</tr>
<tr>
<td>Record vital signs</td>
<td>Quality, safety, and efficiency</td>
<td>76</td>
<td>92</td>
<td>21%</td>
</tr>
<tr>
<td>Active medication lists</td>
<td>Quality, safety, and efficiency</td>
<td>75</td>
<td>87</td>
<td>16%</td>
</tr>
<tr>
<td>Clinical decision support rule</td>
<td>Quality, safety, and efficiency</td>
<td>75</td>
<td>87</td>
<td>16%</td>
</tr>
<tr>
<td>Drug interaction checks</td>
<td>Quality, safety, and efficiency</td>
<td>72</td>
<td>85</td>
<td>18%</td>
</tr>
<tr>
<td>Protect electronic health information</td>
<td>Privacy and security</td>
<td>NR</td>
<td>82</td>
<td>NR</td>
</tr>
<tr>
<td>Electronic copy of health information</td>
<td>Engage patients and families</td>
<td>50</td>
<td>81</td>
<td>62%</td>
</tr>
<tr>
<td>Clinical summaries</td>
<td>Engage patients and families</td>
<td>70</td>
<td>81</td>
<td>16%</td>
</tr>
<tr>
<td>Maintain problem lists</td>
<td>Quality, safety, and efficiency</td>
<td>57</td>
<td>78</td>
<td>37%</td>
</tr>
<tr>
<td>Clinical quality measures</td>
<td>Quality, safety, and efficiency</td>
<td>47</td>
<td>76</td>
<td>62%</td>
</tr>
<tr>
<td>Clinical information exchange</td>
<td>Care coordination</td>
<td>63</td>
<td>72</td>
<td>14%</td>
</tr>
<tr>
<td>CPOE for medication orders</td>
<td>Quality, safety, and efficiency</td>
<td>51</td>
<td>72</td>
<td>41%</td>
</tr>
<tr>
<td><strong>Stage 1 Menu Measures</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medication reconciliation</td>
<td>Care coordination</td>
<td>89</td>
<td>93</td>
<td>4%</td>
</tr>
<tr>
<td>Patient lists</td>
<td>Quality, safety, and efficiency</td>
<td>70</td>
<td>89</td>
<td>27%</td>
</tr>
<tr>
<td>Clinical lab test results</td>
<td>Quality, safety, and efficiency</td>
<td>62</td>
<td>89</td>
<td>44%</td>
</tr>
<tr>
<td>Drug formulary checks</td>
<td>Quality, safety, and efficiency</td>
<td>74</td>
<td>85</td>
<td>15%</td>
</tr>
<tr>
<td>Patient-specific education</td>
<td>Engage patients and families</td>
<td>63</td>
<td>83</td>
<td>32%</td>
</tr>
<tr>
<td>Advanced directives</td>
<td>Quality, safety, and efficiency</td>
<td>67</td>
<td>80</td>
<td>19%</td>
</tr>
<tr>
<td>Transition of care summary</td>
<td>Care coordination</td>
<td>52</td>
<td>77</td>
<td>48%</td>
</tr>
<tr>
<td>Immunization registries</td>
<td>Public and population health</td>
<td>47</td>
<td>63</td>
<td>34%</td>
</tr>
<tr>
<td>Lab results to public health agencies</td>
<td>Public and population health</td>
<td>44</td>
<td>57</td>
<td>30%</td>
</tr>
<tr>
<td>Syndromic surveillance</td>
<td>Public and population health</td>
<td>41</td>
<td>55</td>
<td>34%</td>
</tr>
</tbody>
</table>

NR = not reported; the 2011 estimate for Protect Electronic Health Information was not reliable.

NOTE: All differences are statistically significant from the previous year (p < 0.05).

SOURCE: ONC/AHA, AHA Annual Survey Information Technology Supplement
Ambulatory Meaningful Use

- 388,000 “eligible providers” registered so far for the meaningful use incentive program
  - 73% of the eligible population nationally
- 230,000 “eligible providers” have received meaningful use incentives
  - 44% of the eligible population nationally
- 1700 unique certified EHR products

CPOE Effects on Care – Reviews

- 68% of 70 CDS studies showed positive effects on care processes
  - Kawamoto, Annals of IM 2005
    - Independent predictors in meta-regression:
      - Decision support is...
        • automatically part of clinician workflow
        • recommendations rather than just assessments
        • provided at the time and location of decision making
        • computer based

- 25% of 257 HIT studies from 4 institutions (“homegrown” systems)
  - Chaudhry, Annals of IM 2006
    - Indiana/Regenstrief
    - LDS Hospital/Intermountain Health Care
    - VA
    - Brigham & Women’s
More Recent Results More Positive

Evaluations Of Outcome Measures Of Health Information Technology: A total of 278 outcome measures were evaluated across all studies.

• Diagnostic expert systems
  – **Concept:** Make a table of all symptoms and diseases
    [Ledley & Lusted, 1959]
  – **Attempts**
    • Input symptoms, get list of possibilities
    • Internist (1972-1984)
      – 600 diseases, 4250 findings
      – Converted to “QMR” electronic textbook, 1985
    • DXPlain, Illiad
Clinical Decision Support (CDS)

- MYCIN: meningitis Rx [Shortliffe, 1973]
  - Made up of “production rules”
    - If organism is gram positive and grows in clumps then organism is more likely staphylococcus (0.7)
  - Forward-chaining
    - If A then B  
    - If B and E then F
    - If C then E
    - If A and D then G
  - Success: Credit card fraud detection
Diagnostic CDS

• Performance
  – 105 “difficult” cases input into 4 DSS
    • each with “correct” and “relevant” dx’s
  – 52-71% of lists included correct dx
  – < 50% of all “relevant” dx’s included
  – 19-37% of suggested dx’s “relevant”
    • 2 extras/case “relevant” in retrospect
  – No differences among systems

[Berner, 1994]
CDS: Early Findings

• Reminders
  – Printed with encounter note
    • e.g. “BP elevated, suggest med change”
  – Effective (but no learning)
    • 22% adherence without reminder
    • 51% adherence with reminder
    • Return to baseline when reminder off

[McDonald, 1976]
CDS Early Findings

- Utah Antibiotic Advisor
  - Guideline advice with antibiotic order entry
  - Net use of antibiotics ↓ 23% (time series, adj.)

[Pestotnik, 1998; Evans, 1998]

<table>
<thead>
<tr>
<th>In ICU</th>
<th>Abx cost</th>
<th>Total cost</th>
<th>LOS</th>
<th>Errors</th>
<th>AEs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year before</td>
<td>$340</td>
<td>$35,283</td>
<td>12.9</td>
<td>405</td>
<td>28</td>
</tr>
<tr>
<td>Followed</td>
<td>$102</td>
<td>$26,315</td>
<td>10.0</td>
<td>87</td>
<td>4</td>
</tr>
<tr>
<td>Not followed</td>
<td>$407</td>
<td>$44,865</td>
<td>16.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
IT projects often fail

• Mythical man-month [Brooks, 1975]
  – labor and productivity sometimes correlate *inversely*

• Survey of IT executives, 1994 to 2002 [The Standish Group, 2003]
  – 13,000 identified projects:
    • completed on time and on budget: 16% ⇒ 34%
    • failed and were cancelled: 31% ⇒ 15%
    • cost or time overrun: 53% ⇒ 51%
      – 42% cost, 83% time
• Computational complexity theory
  – Compute time may grow non-linearly with size of the problem
  – e.g. the traveling salesman: best route to visit all?

[Diagram showing a network of points A, B, C, D with routes between them, and a map with streets and locations.]
Basic Concepts

• Tractability
  – Compute time may grow exponentially with size of the problem space
    \( O(e^n) \) vs. \( O(n^2) \)
  – e.g. routes \( e^n \) for salesman, \( n \) cities
  – Improving compute speed little help

<table>
<thead>
<tr>
<th>( n )</th>
<th>( e^n ) (msec)</th>
<th>( \text{years} )</th>
<th>( n^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.718</td>
<td>8.6E-11</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>148</td>
<td>4.7E-09</td>
<td>25</td>
</tr>
<tr>
<td>10</td>
<td>22,026</td>
<td>7.0E-07</td>
<td>100</td>
</tr>
<tr>
<td>20</td>
<td>485,165,195</td>
<td>0.015</td>
<td>400</td>
</tr>
<tr>
<td>30</td>
<td>( 1.07 \times 10^{13} )</td>
<td>338</td>
<td>900</td>
</tr>
<tr>
<td>40</td>
<td>( 2.35 \times 10^{17} )</td>
<td>7.5 M</td>
<td>1600</td>
</tr>
<tr>
<td>50</td>
<td>( 5.18 \times 10^{21} )</td>
<td>160 B</td>
<td>2500</td>
</tr>
<tr>
<td>1 million x speed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>1.07E+07</td>
<td>3 hours</td>
<td>900</td>
</tr>
<tr>
<td>44</td>
<td>1.29E+13</td>
<td>410</td>
<td>1936</td>
</tr>
</tbody>
</table>
Facets of Biomedical Informatics

• Biomedical informatics in **translational research**
  – **Clinical Research Informatics (CRI)** is concerned with the development, application, and evaluation of theories, methods, and systems to optimize the design and conduct of clinical research and the analysis, interpretation, and dissemination of the information generated.
    • Management of information related to clinical trials
    • Secondary use of clinical data for research

• Biomedical Informatics Program
  – Leadership
    • Douglas Bell, MD, PhD
    • Paul Fu, Jr. MD, MPH
    • Omolola Ogunyemi, PhD
    • Kent Taylor, PhD
  – Services
    • complex databases
    • clinical data access
    • online, email-prompted surveys
    • terminology systems
    • online systems to support research
    • informatics tools
  – Example tools
    • UC Data Explorer
    • REDCap
## Informatics Resources

<table>
<thead>
<tr>
<th>Research Task</th>
<th>Informatics Resource</th>
</tr>
</thead>
</table>
| Hypothesis generation, cohort preparation (intra- and inter-institutional), epidemiology | UC-ReX Data Explorer  
Los Angeles Data Resource (LADR)                                    |
| Subject recruitment, protocol management                                       | Clinical Trial Management System                           |
| Data management                                                               | REDCap                                                     |
|                                                                               | **Discussed in Module 8 Part V**                           |
| Standardized terminologies and vocabularies                                    | Common Terminology Services                                |
| Researcher networking, access services                                         | CTSI Virtual Home                                           |

**Resources highlighted in green are currently available**
• UC ReX Data Explorer
  – Allows authorized UC researchers to query de-identified diagnosis and procedure data across all patient records
    • 11.8 million patient records
    • All 5 UC academic medical centers
  – Provides secure, web-based, local access to shared database
  – Includes patient demographics, diagnosis, and procedures data
UC ReX Demo
Clinical Data Warehouse at UCLA

• The Office of Health Informatics and Analytics (OHIA)
  – Mohammed Mahbouba, Chief Informatics Officer
  – Charged to expand CareConnect capabilities to improve patient care, research, and educational opportunities.

• Funded jointly by the UCLA CTSI, DGSOM and the UCLA Health System

• An Enterprise Data Warehouse (called “xDR”) is the core technology provided by the new office.

• Services are available to department decision-support functions, the CTSI Biomedical Informatics Program, Health System Operations teams, the FPG, the Office for Innovation, etc.
Enterprise Systems Roadmap

**Reporting Workbench**
Real-time operational Reporting
1600 Released Reports

**Clarity Reporting**
Crystal Reports
840 Released Reports

**SAP Business Objects Suite**
Interactive Reports
Dashboards
Recombinant Selectrus
Analytics

**Packaged Analytical Solution**
Specialized Data Marts (Quality, Operations, Research, etc.)
Advanced Analytics (NLP, Predictive Modeling, Forecasting, Data Mining, etc.)
What is LADR?

• Los Angeles Data Repository (LADR)
  – Link data across CTSI institutions
    • For clinical cohort discovery
    • For comparative effectiveness research
      – Need data linked at the patient level
      – “Private record linkage”: uses encrypted patient info; no PHI release needed
  – Empower research that would be impossible for any single institution based on its own data
  – Establish governance to protect each institution’s autonomy
  – Target expansion beyond the initial CTSI partners, e.g. Kaiser, USC
LADR: Other Key Features

• For CER, no identification of care delivery site
  – Ultimately, care appears as if from one big organization
  – Unless a unanimously-approved compelling need

• Target data to be extracted based on concrete studies from a few pilot investigators
Clinical Trial Management System

• Software architecture to manage data involved with the execution of a clinical trial
  – Manages planning, preparation, and reporting
    • Patient recruitment
    • Protocol management
    • Budgeting
    • Data safety monitoring
    • Adverse event reporting
    • Case report form development
    • Electronic data capture
  – Connect with existing electronic health record data (CareConnect)
• Selection of an institution-wide CTMS product is underway at UCLA
Common Terminology Services

• **Data interoperability**
  – Clinical data standards: Agreed upon rules that allow information to be shared among different systems and organizations

• **Access to up-to-date standardized content**
  – Terminology standards
    • SNOMED CT
    • ICD-9/10
    • LOINC
  – Messaging standards
    • Health level seven (HL7)
    • Continuity of care record (CCR)

• **Software tools to manage terminologies, code sets, and terminologies**
  – Apelon TermManager
SNOMED

- **Standard Nomenclature of Diseases and Operations (SNDO)**
  - NYAS, 1928; AMA to 1961
    - Multi-axial: Etiology, Topography, etc.
      - Prostate cancer = Adenocarcinoma + Prostate location
    - 1959 AHA study comparing with ICD-9: SNDO inefficient
  - 1965, College of Am. Pathologists
    - Systematized Nomenclature of Pathology (SNOP)
      - 4 axes

- **Systematized Nomenclature of Medicine (SNOMED)**
  - 1979 to 2005: grew to 11 axes

- **SNOMED-CT**
  - $25M investment from U.S. National Library of Medicine (free in U.S.)
  - 1999 – 2007 SNOMED merged with UK NHS Read Codes
  - Ownership moved to a Denmark nonprofit IHTSDO
  - 300,000 concepts; 737,695 synonyms
  - Extensively hierarchies for logical reasoning
RxNorm Ontology

- **Ingredient**
  - e.g. 18631 Azithromycin

- **Clinical Drug Form**
  - e.g. 370976 Azithromycin Oral Tablet

- **Clinical Drug Component**
  - e.g. 315449 Azithromycin 250 MG

- **Dose Form**
  - e.g. 317541 Oral Tablet

- **Branded Drug Form**
  - e.g. 367697 Azithromycin Oral Tablet [Zithromax]

- **Branded Drug Component**
  - e.g. 564001 Azithromycin 250 MG [Zithromax]

- **Semantic Clinical Drug**
  - 308460 Azithromycin 250 MG Oral Tablet

- **Semantic Branded Drug**
  - 212446 Azithromycin 250 MG Oral Tablet [Zithromax]

- **Brand Name**
  - e.g. 196474 Zithromax

- **constitutes** / **consists_of**
  - ingredient_of / **has_ingredient**

- **isa** / **inverse_isa**
  - dose_form / **has_dose_form**

Credit: John Kilbourne, NLM
Summary

• Biomedical informatics
  – Impact on healthcare
    • Adoption of EHRs is growing
      – 44% of hospitals and eligible providers both
    • While mixed, a growing body of evidence demonstrates a reduction in adverse events and mortality when utilizing computerized provider order entry
  – Impact on clinical research
    • Reduce the time required to move basic science research to clinical practice
    • Informatics services are being deployed to facilitate the process across CTSI member sites (UC ReX, LADR)

• Informatics should be considered during the planning stages of any research project
  – Data management, large-scale analysis, collaboration/sharing

• Growing need for research and education in informatics
Additional Resources

• Medical Informatics organizations:
  – AMIA (American Medical Informatics Assoc’n)

• Journals and proceedings:
  – JAMIA (Journal of AMIA)
  – Medical Decision Making
  – Methods of Information in Medicine
  – Proceedings of the AMIA Symposium

• Funding
  – Most: NLM, AHRQ
  – Also: CMS, NSF, RWJ, industry