CTSI Module 5 Workshop
Biomedical Informatics

Organizers: Corey Arnold, PhD & William Hsu, PhD
Medical Imaging Informatics Group
Dept of Radiological Sciences
UCLA School of Medicine
Module Objectives

**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>Introductory Topics</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 what is biomedical informatics and its subfields</td>
<td>• Describe the use of standards for data coding, knowledge representation and exchange of clinical information</td>
<td>• Discuss software tools and resources for data collection, extraction and representation, and analysis</td>
</tr>
<tr>
<td>• Describe the role of informatics in improving public health and care delivery</td>
<td>• Discuss the importance of controlled terminologies as a specific class of standards</td>
<td>• Introduce machine learning methods and tools</td>
</tr>
<tr>
<td>• Learn about computational challenges and available campus resources for translational bioinformatics</td>
<td>• Learn about health information system architecture</td>
<td>• Showcase resources available through the CTSI, member campuses, and the UC system</td>
</tr>
<tr>
<td>Date</td>
<td>Lecture Topic</td>
<td>Instructor(s)</td>
</tr>
<tr>
<td>--------</td>
<td>----------------------------------------------</td>
<td>-----------------------------------------</td>
</tr>
<tr>
<td>5/6</td>
<td><strong>5A</strong> Introduction to biomedical informatics</td>
<td>Douglas Bell, MD, PhD</td>
</tr>
<tr>
<td>5/8</td>
<td><strong>5B</strong> Public health informatics</td>
<td>Paul Fu, Jr MD MPH</td>
</tr>
<tr>
<td>5/13</td>
<td><strong>5C</strong> Data standards</td>
<td>Robert Jenders MD, MS</td>
</tr>
<tr>
<td>5/15</td>
<td><strong>5D</strong> Clinical decision support</td>
<td>Robert Jenders MD, MS</td>
</tr>
<tr>
<td>5/20</td>
<td><strong>5E</strong> Bioinformatics</td>
<td>Eleazar Eskin PhD</td>
</tr>
<tr>
<td>5/22</td>
<td><strong>5F</strong> Data collection &amp; analysis</td>
<td>David Elashoff PhD</td>
</tr>
<tr>
<td>5/27</td>
<td><strong>5G</strong> Advanced topics &amp; machine learning</td>
<td>Corey Arnold PhD &amp; William Hsu PhD</td>
</tr>
</tbody>
</table>
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
  – UCRex
    http://www.ctsi.ucla.edu/research/pages/ucrex
  – xDR
    http://www.ctsi.ucla.edu/research/pages/xDR
  – LADR
    http://www.ctsi.ucla.edu/research/pages/LADR
  – UCLA Darling Biomedical Library Workshop Series
    http://uclabiomed.eventbrite.com/
CTSI Module 5 Workshop
Biomedical Informatics

Session 5A: Introduction to Biomedical Informatics

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

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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)

Source: William Hersh, Oregon Health Science University
Biomedical Informatics & HIT

Biomedical Informatics

Training, Research and Development
- Academia
- Research Institutes
- Corporate Research Labs

Health Information Technology

Clinical Systems Companies

Hospitals, Health Systems, Practices, Healthcare Industry

Academic Medical Centers

methods & ideas

synergies

Source: American Medical Informatics Association
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

Structure  →  Process  →  Outcomes

CPOE  →  Med errors  →  Mortality
CDS  →  Quality measures  →  QOL
EHR usability  →  EHR use  →  BP control
User training  →  User errors  →  Adverse events
Patient Safety: Definitions

• 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

<table>
<thead>
<tr>
<th>Type of Event</th>
<th>No. of Events in Sample</th>
<th>Weighted Proportion of Events*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>in population</td>
</tr>
<tr>
<td>Operative</td>
<td></td>
<td>percent</td>
</tr>
<tr>
<td>Wound infection</td>
<td>160</td>
<td>13.6</td>
</tr>
<tr>
<td>Technical complication</td>
<td>157</td>
<td>12.9</td>
</tr>
<tr>
<td>Late complication</td>
<td>137</td>
<td>10.6</td>
</tr>
<tr>
<td>Nontechnical complication</td>
<td>87</td>
<td>7.0</td>
</tr>
<tr>
<td>Surgical failure</td>
<td>58</td>
<td>3.6</td>
</tr>
<tr>
<td>All</td>
<td>599</td>
<td>47.7</td>
</tr>
<tr>
<td>Nonoperative</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drug-related</td>
<td>178</td>
<td>19.4</td>
</tr>
<tr>
<td>Diagnostic mishap</td>
<td>79</td>
<td>8.1</td>
</tr>
<tr>
<td>Therapeutic mishap</td>
<td>62</td>
<td>7.5</td>
</tr>
<tr>
<td>Procedure-related</td>
<td>88</td>
<td>7.0</td>
</tr>
<tr>
<td>Fall</td>
<td>20</td>
<td>2.7</td>
</tr>
<tr>
<td>Fracture§</td>
<td>18</td>
<td>1.2</td>
</tr>
<tr>
<td>Postpartum§</td>
<td>18</td>
<td>1.1</td>
</tr>
<tr>
<td>Anesthesia-related</td>
<td>13</td>
<td>1.1</td>
</tr>
<tr>
<td>Neonatal</td>
<td>29</td>
<td>0.9</td>
</tr>
<tr>
<td>System and other</td>
<td>29</td>
<td>3.3</td>
</tr>
<tr>
<td>All</td>
<td>534</td>
<td>52.3</td>
</tr>
</tbody>
</table>
Projection

• 33.6 Million hospital admissions
  
  (3.7% AEs x 13.6% fatal x 58% preventable) 
  = 98,000 preventable deaths 

  (2.9% AEs x 6.6% fatal x 68% preventable) 
  = 44,000 preventable deaths 

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

[Kohn, 2000]
Adverse Drug Events

• 1995: ADE Prevention Study
  – 2 hospitals: prospectively identified med errors
  – 6.5 ADEs/100 admissions
    • 1.8 preventable, 4.7 non-preventable

Table 4.—Distribution of Errors by Proximal Cause and Stage of Drug Ordering and Delivery

<table>
<thead>
<tr>
<th>Proximal Cause</th>
<th>Physician Ordering, No. (%)</th>
<th>Transcription and Verification, No. (%)</th>
<th>Pharmacy Dispensing, No. (%)</th>
<th>Nurse Administration, No. (%)</th>
<th>All, No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of knowledge of the drug</td>
<td>47 (36)</td>
<td>6 (15)</td>
<td>0 (0)</td>
<td>19 (15)</td>
<td>72 (22)</td>
</tr>
<tr>
<td>Lack of information about the patient*</td>
<td>31 (24)</td>
<td>4 (10)</td>
<td>0 (0)</td>
<td>13 (10)</td>
<td>48 (14)</td>
</tr>
<tr>
<td>Rule violations</td>
<td>25 (19)</td>
<td>0 (0)</td>
<td>6 (16)</td>
<td>2 (2)</td>
<td>33 (10)</td>
</tr>
<tr>
<td>Slips and memory lapses</td>
<td>14 (11)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>15 (12)</td>
<td>29 (9)</td>
</tr>
<tr>
<td>Transcription errors</td>
<td>0 (0)</td>
<td>29 (73)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>29 (9)</td>
</tr>
<tr>
<td>Faulty drug identity checking†</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>11 (29)</td>
<td>13 (10)</td>
<td>24 (7)</td>
</tr>
<tr>
<td>Faulty interaction with other services</td>
<td>1 (1)</td>
<td>0 (0)</td>
<td>3 (8)</td>
<td>13 (10)</td>
<td>17 (5)</td>
</tr>
<tr>
<td>Faulty dose checking</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>3 (8)</td>
<td>13 (10)</td>
<td>16 (5)</td>
</tr>
<tr>
<td>Infusion pump and parenteral delivery problems</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>16 (13)</td>
<td>16 (5)</td>
</tr>
<tr>
<td>Inadequate monitoring</td>
<td>11 (8)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>4 (3)</td>
<td>15 (4)</td>
</tr>
<tr>
<td>Drug stocking and delivery problems</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>11 (29)</td>
<td>0 (0)</td>
<td>11 (3)</td>
</tr>
<tr>
<td>Preparation errors</td>
<td>0 (0)</td>
<td>4 (11)</td>
<td>0 (0)</td>
<td>6 (5)</td>
<td>10 (3)</td>
</tr>
<tr>
<td>Lack of standardization</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>8 (6)</td>
<td>8 (2)</td>
</tr>
<tr>
<td>Unclassified</td>
<td>1 (1)</td>
<td>1 (3)</td>
<td>0 (0)</td>
<td>4 (3)</td>
<td>6 (2)</td>
</tr>
<tr>
<td><strong>Totals‡</strong></td>
<td><strong>130 (100)</strong></td>
<td><strong>40 (100)</strong></td>
<td><strong>38 (100)</strong></td>
<td><strong>126 (100)</strong></td>
<td><strong>334 (100)</strong></td>
</tr>
</tbody>
</table>
CPOE for ADE Prevention

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

• ... vs. CPOE after additional refinements:
  – Non-intercepted serious errors $\rightarrow$ 1.1 (86%)
    • But intercepted
      K$^+$ errors initially increased

![Graph showing rate per 1000 patient-days across Baseline, Period 1, Period 2, and Period 3.]
IT System Errors

- 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

Role of Computerized Physician Order Entry Systems in Facilitating Medication Errors

Ross Koppel, PhD
Joshua P. Metlay, MD, PhD
Abigail Cohen, PhD
Brian Abaluck, BS
A. Russell Localio, JD, MPH, MS
Stephen E. Kimmel, MD, MSCE
Brian L. Strom, MD, MPH

Context: Hospital computerized physician order entry (CPOE) systems are widely regarded as the technical solution to medication ordering errors, the largest identified source of preventable hospital medical error. Published studies report that CPOE reduces medication errors up to 81%. Few researchers, however, have focused on the existence or types of medication errors facilitated by CPOE.

Objective: To identify and quantify the role of CPOE in facilitating prescription error risks.

Design, Setting, and Participants: We performed a qualitative and quantitative study of house staff interaction with a CPOE system at a tertiary-care teaching hos-
Koppel surveyed 95 housestaff about frequency of errors.
More Major Challenges

• Ordering takes longer (esp. when learning)
  – History of resident revolt at UVa [Massaro, 1993]

• Pediatric ICU CPOE at Pitt:
  – 2.8% mortality in 13 mo. before $\rightarrow$ 6.6% in 5 mo. after
    • Couldn’t write orders until pt. registered in ICU system
    • Delay in starting antibiotics
  • Han, Pediatrics 2005
Observed mortality rates (presented as a normalized % of predicted mortality) during the 18-month study period are plotted according to quarter of year.

Hospital-wide mortality rate per 100 discharges according to month (excluding the obstetrical population).

Longhurst C A et al. Pediatrics 2010;126:14-21
Variance in System Features

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

Wang, JAMIA 2005
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 – 402 KB]
If You Install It, Will They Use?

- **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
• 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
  – Karen DeSalvo, MD
“Meaningful Use”

Stage 1
Store Coded and Structured Information in the EMR

Stage 2
Begin Vigorous Data Exchange to Promote Coordinated Care

Stage 3
Improved Outcomes and Reduced Costs Shown through Robust Set of Quality Reports

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

25% increase in prescribers routing prescriptions in 2012

• “Any EHR system” is a medical or health record system that is either all or partially electronic (excluding systems solely for billing).

• “Basic EHR system” has all of the following: patient history and demographics, patient problem lists, physician clinical notes, comprehensive list of patients' medications and allergies, computerized orders for prescriptions, and ability to view laboratory and imaging results electronically.
EHR Adoption: Ambulatory

Figure 2. Percentage of office-based physicians with a basic EHR system, by state: United States, 2013

National average: 48.1

* Estimate does not meet standards of reliability or precision.
NOTES: EHR is electronic health record. Significance tested at p < 0.05.
SOURCE: CDC/NCHS, National Ambulatory Medical Care Survey, Electronic Health Records Survey.
EHR Adoption: Hospitals

<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>Electronic Clinical Information</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Patient demographics</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<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>
<td>*</td>
<td>*</td>
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<tr>
<td>Medication lists</td>
<td>*</td>
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<td>Discharge summaries</td>
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<tr>
<td>Advance directives</td>
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<tr>
<td>Computerized Provider Order Entry</td>
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<tr>
<td>Lab reports</td>
<td>*</td>
<td></td>
<td></td>
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<tr>
<td>Radiology tests</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Medications</td>
<td>*</td>
<td>*</td>
<td>*</td>
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<tr>
<td>Consultation requests</td>
<td>*</td>
<td>*</td>
<td>*</td>
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<tr>
<td>Nursing orders</td>
<td>*</td>
<td>*</td>
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<tr>
<td>Results Management</td>
<td></td>
<td></td>
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<tr>
<td>View lab reports</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>View radiology reports</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>View radiology images</td>
<td>*</td>
<td>*</td>
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</tr>
<tr>
<td>View diagnostic test results</td>
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</tr>
<tr>
<td>View diagnostic test images</td>
<td>*</td>
<td>*</td>
<td>*</td>
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<tr>
<td>View consultant report</td>
<td></td>
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<tr>
<td>Decision Support</td>
<td></td>
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<tr>
<td>Clinical guidelines</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clinical reminders</td>
<td>*</td>
<td></td>
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<tr>
<td>Drug allergy results</td>
<td>*</td>
<td></td>
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<tr>
<td>Drug-drug interactions</td>
<td>*</td>
<td></td>
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<tr>
<td>Drug-lab interactions</td>
<td>*</td>
<td></td>
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<tr>
<td>Drug dosing support</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

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

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

<table>
<thead>
<tr>
<th>Stage 1 Core Measures</th>
<th>Meaningful Use Objective</th>
<th>2011</th>
<th>2012</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<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>
</tbody>
</table>

### Stage 1 Menu Measures

<table>
<thead>
<tr>
<th>Stage 1 Menu Measures</th>
<th>Meaningful Use Objective</th>
<th>2011</th>
<th>2012</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<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

Source: Office of National Coordinator for Health IT, March 2013 brief
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

25% of 257 HIT studies from 4 institutions (“homegrown” systems)

- Indiana/Regenstrief
- LDS Hospital/Intermountain Health Care
- VA
- Brigham & Women’s

**Annals of Internal Medicine**

**Systematic Review: Impact of Health Information Technology on Quality, Efficiency, and Costs of Medical Care**

Basit Chaudhry, MD; Jerome Wang, MD; Shinyi Wu, PhD; Margaret Maglione, MPP; Walter Mojica, MD; Elizabeth Roth, MA; Sally C. Morton, PhD; and Paul G. Shekelle, MD, PhD

**Background:** Experts consider health information technology key to improving efficiency and quality of health care.

**Purpose:** To systematically review evidence on the effect of health information technology on quality, efficiency, and costs of health care.

**Data Sources:** The authors systematically searched the English-language literature indexed in MEDLINE (1995 to January 2004), the Cochrane Central Register of Controlled Trials, the Cochrane Database of Abstracts of Reviews of Effects, and the Periodical Abstracts Database. We also added studies identified by experts up to April 2005.

Approximately 25% of the studies were from 4 academic institutions that implemented internally developed systems; only 9 studies evaluated multifunctional, commercially developed systems. Three major benefits on quality were demonstrated: increased adherence to guideline-based care, enhanced surveillance and monitoring, and decreased medication errors. The primary domain of improvement was preventive health. The major efficiency benefit shown was decreased utilization of care. Data on another efficiency measure, time utilization, were mixed. Empirical cost data were limited.

**Limitations:** Available quantitative research was limited and was done by a small number of institutions. Systems were heterogeneous and sometimes incompletely described. Available financial data were limited.
Evaluations Of Outcome Measures Of Health Information Technology A total of 278 outcome measures were evaluated across all studies.

Clinical Decision Support (CDS)

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

Updated RAND Review
  - Jones, Annals of IM, 2014
    - 56% reported uniformly positive results;
      additional 21% reported mixed-positive effects
    - Poor reporting of context and implementation;
      61% of studies did not report any contextual details beyond basic information.
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
Basic Concepts

• Computational complexity theory
  – Compute time may grow nonlinearly with size of the problem
  – e.g. the traveling salesman: best route to visit all?
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>
</tbody>
</table>

1 million x speed

<table>
<thead>
<tr>
<th>( n )</th>
<th>( e^n ) (msec)</th>
<th>( \text{years} )</th>
<th>( n^2 )</th>
</tr>
</thead>
<tbody>
<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>
• 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
UCLA CTSI

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

** Resources highlighted in green are currently available
UC ReX

• 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
• **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
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