Medical Informatics

Stephen J. Ruffenach, DO, MS
Hospitalist, Oro Valley Hospital
Director of Informatics,
EmCare Hospitalist Group
Information and Technology

• “It will produce forgetfulness in the minds of those who learn to use it “

Socrates 370 BC

Regarding the invention of writing

Technology will always move forward and always produce positive and negative changes.
Changes are Coming
Clinical Decisions Today

- Patients
- Man
- Medical
- Machines
- CDSS
- Doctors
- Medicine
Clinical Decision Support (CDS) Defined

- Clinical Decision Support (CDS) is a process designed to aid directly in clinical decision making, in which **characteristics of individual patients** are used to generate **patient specific interventions, assessments, recommendations, or other forms of guidance** that are **then presented to a decision making recipient or recipients** that can include clinicians, patients, and others involved in care delivery.

  - http://www.healthit.gov
Man

We’ve grown
In numbers

Not so much in size

<table>
<thead>
<tr>
<th>Who</th>
<th>Homo Heidelbergensis</th>
<th>Neanderthal</th>
<th>Homo sapien</th>
<th>Modern man</th>
</tr>
</thead>
<tbody>
<tr>
<td>When</td>
<td>500,000 yrs ago</td>
<td>100,000 yrs ago</td>
<td>1000 yrs ago</td>
<td>Now</td>
</tr>
<tr>
<td>How many</td>
<td>&lt; 1 million</td>
<td>1 million</td>
<td>50 million</td>
<td>6.5 billion</td>
</tr>
<tr>
<td>Height (inches)</td>
<td>69</td>
<td>65</td>
<td>68</td>
<td>69</td>
</tr>
<tr>
<td>Time</td>
<td>Action</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>400 BC</td>
<td>Observation and Reason</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>200 AD</td>
<td>Surgery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>200 AD</td>
<td>Accupuncture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1200 AD</td>
<td>Medical Schools</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1543 AD</td>
<td>Anatomy and Physiology</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1850 AD</td>
<td>Germ Theory</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1903s</td>
<td>EKG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1950s</td>
<td>Antibiotics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1990s</td>
<td>Genome</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Machines

- Technology advances continuously
- Machines are a by-product of that advancement
- Modern medicine advances with technology and machines
- Moore’s Law clarifies the rate of the advancement
Computational Power and Machines March On

1. The accelerating pace of change...
   - Agricultural Revolution: 8,000 years
   - Industrial Revolution: 120 years
   - Light-bulb: 90 years
   - Moon landing: 22 years
   - World Wide Web: 9 years
   - Human genome sequenced: 10^16

2. ...and exponential growth in computing power...
   - Computer technology, shown here climbing dramatically by powers of 10, is now progressing more each hour than it did in its entire first 90 years.

3. ...will lead to the Singularity
   - Apple II: At a price of $1,298, the compact machine was one of the first massively popular personal computers.
   - Power Mac G4: The first personal computer to deliver more than 1 billion floating-point operations per second.

Time Magazine, February 10, 2014
Clinical Decision Making in the New World

Man -> Interpersonal
CDSS
Technical
Machines
Methodical

Medical
Why CDSS Will Become Increasingly Important

Clinical Demand
Computational Abilities
Consumer Expectations
Clinical Demand

Medicare Enrollment, 1970-2035

In millions:

- Historical:
  - 1970: 20.4
  - 1975: 24.9
  - 1980: 28.4
  - 1985: 31.1
  - 1990: 34.3
  - 1995: 37.6
  - 2000: 39.7
  - 2005: 42.6
  - 2010: 47.7

- Projected:
  - 2015: 55.6
  - 2020: 64.3
  - 2025: 73.5
  - 2030: 81.5
  - 2035: 86.5

Clinical Demand

• 24% of the US population is > 49 years old

• 17 million are between 75 and 85 years old
  – Will be 30 million by 2045

• Health care costs = 18% of the US GNP
  – 28% spent in last 6 months of life

Lewis, Stephen F
American Journal of Medicine
February 2016
Vol 129, No.2
Clinical Demand

Figure 1. Baseline Physician Full-Time Employee (FTE) Supply and Demand Projections, 2006 – 2025.²
Clinical Demand

SHORTAGE OF PRIMARY CARE PHYSICIANS PROJECTED TO WORSEN

Shortage of FP's, GP's & Internists

Moore’s Law states that available computational power doubles every 18-24 months.
Computational Abilities

<table>
<thead>
<tr>
<th>Year</th>
<th>Developed world</th>
<th>World globally</th>
<th>Developing world</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>11</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>1998</td>
<td>17</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>2000</td>
<td>24</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>2002</td>
<td>31</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>2004</td>
<td>36</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>2006</td>
<td>42</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>2008</td>
<td>51</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>2010</td>
<td>59</td>
<td>16</td>
<td>15</td>
</tr>
<tr>
<td>2012</td>
<td>61</td>
<td>18</td>
<td>17</td>
</tr>
<tr>
<td>2014</td>
<td>63</td>
<td>21</td>
<td>21</td>
</tr>
</tbody>
</table>

- 2 billion internet users worldwide
- by 2017

Main article: List of countries by number of Internet users

Source: International Telecommunications Union.[1][2]
Consumer Expectations

• Patients want their healthcare questions answered:
  – Quickly
  – Compassionately
  – Personalized

• Want their evidence at the individual-patient level
Consumer Expectations

“Where do you find information to make decisions about healthcare?”

The Internet & Doctors Rank Highest; Friends, Family and Media Follow

- Grocery stores/supermarkets: 7%
- Schools: 7%
- Health clubs: 8%
- Community services: 14%
- Social networking websites: 17%
- Government: 21%
- The hospital: 22%
- TV or radio: 24%
- Magazine or newspapers: 27%
- Friends or family: 30%
- Doctors: 43%
- Health website: 48%
Personalized medicine is becoming a reality.

- **Personalised** (Based on 'people like me')
- **Protocol-Based** (Based on best practice)
- **Evidence-Based** (Based on large-scale trials)
- **Clinician consensus**
- **Individual clinician knowledge & experience**

**Access to Clinical Knowledge**
(e.g. Diagnostic tools, Comparative Effectiveness)

**Access to Patient Information**

- **Good**
- **Poor**

**Increasing Quality**

- More art than science
- More science than art

Source: IBM Global Business Services and IBM Institute for Business Value

© 2013 IBM Corporation
Personalized Medicine

Putting the patient at the center of their health system

- Smart Sensing
- Intelligent Information Management
- Effective Interfaces

- Family & Friends
- Healthcare Providers
- Healthcare Institutions
- Repositories
- Web
- Researchers
# Personalized Medicine

## CDS Transformation

<table>
<thead>
<tr>
<th>Clinical Decision Support Today</th>
<th>Clinical Decision Support Tomorrow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary focus process: measures</td>
<td>Primary focus: outcomes</td>
</tr>
<tr>
<td></td>
<td>o LOS</td>
</tr>
<tr>
<td></td>
<td>o Costs</td>
</tr>
<tr>
<td></td>
<td>o Readmissions</td>
</tr>
<tr>
<td></td>
<td>o Mortality</td>
</tr>
<tr>
<td>Venue focused</td>
<td>Continuum of care</td>
</tr>
<tr>
<td>Not quadrant focused</td>
<td>Quadrant focused</td>
</tr>
</tbody>
</table>

![Graph showing mortality and cost data](image-url)
Why We Will Embrace CDSS (and perhaps why we shouldn’t)

- Cost
- Convenience
- Confidence
More Confidence
(Misplaced!)
Why We Need CDSS

• Physicians don’t always do the right thing
• Important clinical procedures often not done

<table>
<thead>
<tr>
<th>Clinical Procedure</th>
<th>Landmark Trial</th>
<th>National Use Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flu vaccination</td>
<td>1968</td>
<td>55%</td>
</tr>
<tr>
<td>Pneumococcal Vac.</td>
<td>1977</td>
<td>36%</td>
</tr>
<tr>
<td>Beta Blocker After MI</td>
<td>1982</td>
<td>62%</td>
</tr>
<tr>
<td>Mammography</td>
<td>1982</td>
<td>62%</td>
</tr>
<tr>
<td>FOBT</td>
<td>1986</td>
<td>17%</td>
</tr>
<tr>
<td>Diabetic Foot Care</td>
<td>1993</td>
<td>20%</td>
</tr>
</tbody>
</table>

Why We Need CDSS

Figure 7:
Adults Receive Only Some of the Recommended Care for Many Common Conditions

Why We Need CDSS

Knowledge processing requirement

Knowledge processing capacity

This gap injures patients

Years ago

Today
Computer Intelligence

- Artificial Intelligence
  - Machine Learning
  - Deep Learning
Artificial Intelligence

• Three Kinds
  – Narrow AI
    • Skilled at one task
      – IBM’s Deep Blue
      – Watson
  – Artificial General Intelligence (AGI)
    • Skilled at a range of tasks
      – Human Level
  – Superintelligent AI
    • Machines are smarter than humans
Machine Learning

• A subdivision of AI

• Machines deciphering data
  – Commonly used today
    • Speech, object, and facial recognition

• Machines recognize patterns
  – Make predictions on their own
    • Deep Patient
Deep Learning

• A subdivision of Machine Learning

• Uses Machine Learning Techniques
  – Taps into Neural Networks
  – Mimic human decision making
  – Very data intensive

• Alpha Go
  – October 2015
Clinical Decision Support (CDS) Defined

- A process designed to aid directly in clinical decision making
- Generate *patient specific interventions*
- *Presented to a decision making recipient or recipients*
- *5 Rights of CDS*
CDS Five Rights

- Deliver the Right information
- To the Right person
- In the Right CDS intervention format
- Through the Right channel
- At the Right point in workflow
How Do CDS Systems Work?

- Combines knowledge base rules with clinical data
- Suggests dx and tx plan

Knowledge Base

- If then rules
- Disease Information

Inference Engine

Data Input

Results Output

http://www.intechopen.com/download/get/type/pdfs/id/18694
How Do CDS Systems Think?

- Deterministic
  - Linear Rule-Based Systems
  - First-order rules applied

- Probabilistic
  - Non-Linear, distributed, parallel processing
  - Neural Networks
Rule-Based Systems

• Forward Chain Rules
  – Start with data, apply rule
  – Use if sparse data

• Backward Chain Rules
  – Start with “goal rule” and apply to each required premise
  – Use if lots of data

• Problems with Rules
  – Contradictory, circular
  – Countless
  – Conformity problems
Neural Networks

• Computational structure modeled after animal’s CNS

• Processes input non-linearly
  – Assign adaptive weights
  – Learn algorithms
  – Approximates outputs
Neural Networks

Accepts various inputs

The hidden layer recodes the data

Each connection has a weight

Multiple outputs are possible
Five Key CDS Types in Current EMR

(Low Hanging Fruit)

1. Order Sets
   - Embedded in EMRs
2. Alerts
   - Patient Care Reminders
3. Referential Content
   - UpToDate
4. Nursing Care Plans
   - Nurselabs.com
   - Careplans.com
5. Drug Database
   - Epocrates
   - Medscape
Stages of Meaningful Use Have Occurred Over Five Years

2011-2012

Stage 1

Data Capture And Sharing

2014

Stage 2

Advanced Clinical Processes

2016

Stage 3

Improved Outcomes
Meaningful Use and CDSS

• Stage 1
  – **Objective:** Implement one clinical decision support rule relevant to specialty or high clinical priority along with the ability to track compliance that rule
  
  **Measure:** Implement one clinical decision support rule

• Stage 2
  – **Objective:** Use clinical decision support to improve performance on high-priority health conditions

  **Measure:** Implement 5 clinical decision support interventions related to 4 or more clinical quality measures
Meaningful Use and CDSS

• Stage 3

• Measure 1:
  – Implement five clinical decision support interventions related to four or more clinical quality outcome measures

• Measure 2:
  – The EP, eligible hospital or CAH has enabled and implemented the functionality for drug-drug and drug allergy interaction checks for the entire EHR reporting period.

http://www.himss.org/ResourceLibrary/VS articleDEV.aspx?ItemNumber=46311
Do CDSS Work?

• Initial studies were not promising
• Reduction in ADEs were the earliest benefits
• Workflow and knowledge management problems hounded most systems
• The human/digital interface is tricky
Clinical Decision Making in the New World

- Man
- Medicine
- Machines

Interpersonal

CDSS

Technical
Methodical
CDSS Studied

Annals of Internal Medicine
January 2014

12,678
CDSS Articles Reviewed

236
Measurable and Meaningful Outcomes

170
Quality Outcomes

47
Safety Outcomes

62
Efficiency Outcomes

doi:10.7326/M13-1531
Table 1. Health IT Evaluation Studies Between 1995 and 2013, by Study Outcome Type

<table>
<thead>
<tr>
<th>Meaningful Use Functionality</th>
<th>Outcome, n</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quality</td>
</tr>
<tr>
<td>Clinical decision support</td>
<td>257</td>
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<tr>
<td>Computerized provider order entry</td>
<td>63</td>
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<tr>
<td>Multifunctional health IT intervention</td>
<td>146</td>
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<td>Patient care reminders</td>
<td>48</td>
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<tr>
<td>e-Prescribing</td>
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<tr>
<td>Patient access to electronic records</td>
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<tr>
<td>Health information exchange</td>
<td>5</td>
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<tr>
<td>Clinical laboratory test results</td>
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<tr>
<td>Medication lists</td>
<td>1</td>
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<tr>
<td>Electronic immunization registries</td>
<td>2</td>
</tr>
<tr>
<td>Other meaningful use*</td>
<td>15</td>
</tr>
<tr>
<td>All meaningful use</td>
<td>573</td>
</tr>
</tbody>
</table>

CDSS Is Working

<table>
<thead>
<tr>
<th>Meaningful Use Functionality</th>
<th>Outcome Result, %</th>
<th>Total, n</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Positive</td>
<td>Mixed</td>
</tr>
<tr>
<td>Clinical decision support</td>
<td>65</td>
<td>17</td>
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<tr>
<td>Computerized provider order entry</td>
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<td>16</td>
</tr>
<tr>
<td>Multifunctional health IT intervention</td>
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<td>33</td>
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<tr>
<td>Health information exchange</td>
<td>64</td>
<td>30</td>
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<td>Patient lists by condition</td>
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<td>e-Prescribing</td>
<td>52</td>
<td>28</td>
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<td>Patient access to electronic records</td>
<td>60</td>
<td>25</td>
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<tr>
<td>Patient care reminders</td>
<td>60</td>
<td>30</td>
</tr>
<tr>
<td>Other meaningful use functionalities†</td>
<td>55</td>
<td>36</td>
</tr>
<tr>
<td><strong>Total meaningful use</strong></td>
<td><strong>60</strong></td>
<td><strong>24</strong></td>
</tr>
</tbody>
</table>
The use of CDSS was associated with

- A significant increase in the rate of appropriate ordering of prophylaxis for VTE
- A significant decrease in the risk of VTE events
Three Key CDS Coming Soon to EMRs (Future Fruit)

• Differential Diagnosis (DDX) Generators
  – Assistance in DDX Generation
  – Reduction in Diagnostic Errors

• Integrated Healthcare Databases
  – Improved Connectivity
    • FHIR

• Personalized Medical Care
  – Human Genome Project
    • Prediction
    • Treatment Confidence
DDX Generators

• “Programs which assist healthcare professionals in clinical decision making by generating a DDX based on a minimum of two items of patient data”.

• The Effectiveness of Electronic Differential Diagnoses (DDX) Generators: A Systematic Review and Meta-Analysis
  – PLOS One Published: March 8, 2016
  – DOI: 10.1371/journal.pone.0148991
Identify: 8548

Screening: 8026

Eligibility: 92

Included: 36


http://journals.plos.org/plosone/article?id=info:doi/10.1371/journal.pone.0148991
DDX Generators Studied

• “Our findings demonstrate that DDX generators have the potential to
  – Improve diagnostic practice
  – Reduce diagnostic error
  – But there is currently insufficient evidence from the existing literature to recommend their routine use by clinicians”.

  Nicholas Riches, et al
  The Effectiveness of Electronic Differential Diagnoses (DDX) Generators: A Systematic Review and Meta-Analysis
  PLOS One Published: March 8, 2016
  DOI: 10.1371/journal.pone.0148991
Integrated Healthcare Databases

• Healthcare data major problem
  – Increasingly digitized
  – Increasingly cloistered

• Connectivity and Privacy Issues

• Financial Issues

• FHIR to the rescue?
FHIR
Fast Healthcare Interoperability Resources

• A standard for exchanging healthcare information electronically
• Aims to simplify implementation without sacrificing information integrity.
• It leverages existing technology for exchanging data between healthcare applications.
• Major buy-in
• Major obstacles
  – BMJ blog March 2016
"The most important question appears not to be "Where can we use computers?" but "Where must we use human beings?"

Marsden S. Blois, MD, FACMI

Clinical Judgment and computers,
"However, in dealing with computers, nothing can be taken for granted. And clinical judgment counts for little unless it rests on a firm base of ordinary human judgment."

Marsden S. Blois, MD, FACMI

What Must We Do?

• **Illuminate**
  – Be wary of “machines taking over”

• **Evaluate**
  – Convenience trumps quality
  – Complacency is the enemy

• **Integrate**
  – Meaningfully use technology

• **Differentiate**
  – From machines
  – From the community

*The successful clinician will cultivate and command expertise in areas that machines cannot perform

Empathy
Sympathy
Physical Contact
Self-awareness*
Where must we use human beings?

• Mayo Clinic in 2006 identified the most important characteristics patients feel a good doctor must possess.

• The ideal clinician is:
  – Confident
  – Empathetic
  – Humane
  – Personal
  – Forthright
  – Respectful
  – Thorough


IBM Watson
Take Home Points

• “The important thing is not to stop questioning. Curiosity has its own reason for existing.”

• Albert Einstein
The past is a foreign country.

They do things differently there.

L. P. Hartley, 1953

The future starts today,

not tomorrow.

Pope John Paul II, 2000