The past is a foreign country.

They do things differently there.

The Go-Between
L. P. Hartley, 1953

CDSS
Clinical Decision Support Systems

The Future of Medicine
and
Why It Will Change Your Practice Forever

Stephen J. Ruffenach, DO, MS
Informatics Director
Northwest Medical Center and Oro Valley Hosp.
Clinical Assistant Professor of Medicine
The University of Arizona
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

---

<table>
<thead>
<tr>
<th>Who</th>
<th>Homo Heidelbergensis</th>
<th>Neanderthal</th>
<th>Homo sapien</th>
<th>Modern man</th>
</tr>
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<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>
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</table>
Medicine

<table>
<thead>
<tr>
<th>Time</th>
<th>Action</th>
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</thead>
<tbody>
<tr>
<td>400 BC</td>
<td>Observation and Reason</td>
</tr>
<tr>
<td>200 AD</td>
<td>Surgery</td>
</tr>
<tr>
<td>200 AD</td>
<td>Accupuncture</td>
</tr>
<tr>
<td>1200 AD</td>
<td>Medical Schools</td>
</tr>
<tr>
<td>1543 AD</td>
<td>Anatomy and Physiology</td>
</tr>
<tr>
<td>1850 AD</td>
<td>Germ Theory</td>
</tr>
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<td>1903s</td>
<td>EKG</td>
</tr>
<tr>
<td>1950s</td>
<td>Antibiotics</td>
</tr>
<tr>
<td>1990s</td>
<td>Genome</td>
</tr>
</tbody>
</table>

Machines are Changing Dramatically
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

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

Man  Medicine

Inter‐personal

CDSS

Technical  Methodical

Machines

Why CDSS Will Become Increasingly Important

Clinical Demand
Computational Abilities
Consumer Expectations
CDSS is Coming

Clinical Demand
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
Computational Abilities

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

Computational Abilities

> 2 billion internet users worldwide

By 2017
Consumer Expectations

• Patients want their healthcare questions answered:
  – Quickly
  – Compassionately
  – Personalized
    • Want their evidence at the individual-patient level

“Where do you find information to make decisions about healthcare?”
*The Internet & Doctors Rank Highest; Friends, Family and Media Follow*

- 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%

PricewaterhouseCoopers, 2010
Personalized Medicine Can Be Realized

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>• LOS</td>
</tr>
<tr>
<td></td>
<td>• Costs</td>
</tr>
<tr>
<td></td>
<td>• Readmissions</td>
</tr>
<tr>
<td></td>
<td>• 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>

Why We Will Embrace CDSS (and perhaps why we shouldn’t)

- Cost
- Convenience
- Confidence
Confidence (Misplaced!)

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

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?

• There are three parts to most CDSS
  – The knowledge base
    • compiled information that is often, but not always, in the form of if-then rules.
    • contains information about diseases and their signs and symptoms.
  – The inference or reasoning engine
    • contains the formulas for combining the rules in the knowledge base with actual patient data.
    • maps the patient signs and symptoms to those diseases and might suggest some diagnoses for the clinicians to consider.
  – The mechanism to communicate with the user

How Do CDS Systems Work?

Data Input → Inference Engine → Knowledge Base → 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
HIT/CDS Is Being Studied

<table>
<thead>
<tr>
<th>Meaningful Use Functionality</th>
<th>Outcome, n</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quality</td>
<td>Efficiency</td>
<td>Safety</td>
<td>All</td>
</tr>
<tr>
<td>Clinical decision support</td>
<td>257</td>
<td>91</td>
<td>69</td>
<td>417</td>
</tr>
<tr>
<td>Computerized provider order entry</td>
<td>63</td>
<td>66</td>
<td>60</td>
<td>189</td>
</tr>
<tr>
<td>Multifunctional health IT intervention</td>
<td>146</td>
<td>100</td>
<td>27</td>
<td>273</td>
</tr>
<tr>
<td>Patient care reminders</td>
<td>48</td>
<td>8</td>
<td>1</td>
<td>57</td>
</tr>
<tr>
<td>e-Prescribing</td>
<td>15</td>
<td>18</td>
<td>15</td>
<td>48</td>
</tr>
<tr>
<td>Patient access to electronic records</td>
<td>17</td>
<td>3</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>Health information exchange</td>
<td>5</td>
<td>10</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>Clinical laboratory test results</td>
<td>4</td>
<td>6</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>Medication lists</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Electronic immunization registries</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Other meaningful use*</td>
<td>15</td>
<td>6</td>
<td>0</td>
<td>21</td>
</tr>
<tr>
<td>All meaningful use</td>
<td>573</td>
<td>310</td>
<td>174</td>
<td>1057</td>
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</tbody>
</table>

IT = information technology.
* Includes patient-specific education, patient lists by condition, summary of care records, and problem lists.


Five Key CDS Types in Current EMR (Future Fruit)

• Differential Diagnosis (DDX) Generators
• Integrated Healthcare Databases
  – FHIR
• Personalized Medical Care
  – Human Genome Project
    • Prediction
    • Treatment Confidence
Meaningful Use

Stages of Meaningful Use Will Occur Over Five Years

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Stage 1</td>
<td>Stage 2</td>
<td>Stage 3</td>
</tr>
<tr>
<td>Data Capture And Sharing</td>
<td>Advanced Clinical Processes</td>
<td>Improved Outcomes</td>
</tr>
</tbody>
</table>

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

- **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
Does CDSS Work?

- Initial studies were not promising
- Reduction in ADEs were the earliest benefits
- Workflow and knowledge management problems hounded most systems
- Now the tide is changing.
  – Annals of Internal Medicine January 2014 studied CDSS

CDSS Studied

Annals of Internal Medicine
January 2014

236 Measurable and Meaningful Outcomes

170 Quality Outcomes

47 Safety Outcomes

62 Efficiency Outcomes

doi:10.7326/M13-1531
## CDSS Studied

**Table 1. Health IT Evaluation Studies Between 1995 and 2013, by Study Outcome Type**

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<tr>
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</table>


## CDSS Is Working

**Table 2. Health IT Evaluation Studies Between 2007 and 2013, by Study Outcome Result**

<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>
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<tr>
<td>Clinical decision support</td>
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<td>17</td>
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<td>Computerized provider order entry</td>
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<tr>
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<td>33</td>
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<tr>
<td>Health information exchange</td>
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<td>30</td>
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<tr>
<td>Patient lists by condition</td>
<td>73</td>
<td>17</td>
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<tr>
<td>e-Prescribing</td>
<td>52</td>
<td>28</td>
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<tr>
<td>Patient access to electronic records</td>
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<td>25</td>
</tr>
<tr>
<td>Patient care reminders</td>
<td>60</td>
<td>30</td>
</tr>
<tr>
<td>Other meaningful use functional test</td>
<td>55</td>
<td>36</td>
</tr>
<tr>
<td>Total meaningful use</td>
<td>60</td>
<td>24</td>
</tr>
</tbody>
</table>

IT = information technology.
* Includes studies from the 2 most recent systematic reviews (Bunin et al [6] and the current review), covering health IT evaluation studies published between July 2007 and August 2013.
† Includes patient-specific education, medication lists, clinical laboratory test results, immunization registries, summary of care records, and problem lists.

CDSS Is Working

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</tr>
<tr>
<td>Other meaningful use functionality</td>
<td>55</td>
<td>36</td>
</tr>
</tbody>
</table>


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

The Effectiveness of Electronic Differential Diagnoses (DDX) Generators: A Systematic Review and Meta-Analysis

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

- 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

What does the future hold?

"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,
What does the future hold?

“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
Clinical Judgment and computers,

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
What Must We Do?

• The successful clinician will cultivate and command expertise in areas that machines cannot perform
  – Empathy
  – Sympathy
  – Physical Contact

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

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