Clinical Decision Support: An Overview

Blackford Middleton, MD, MPH, MSc
Partners Healthcare System – Harvard Medical School

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NLP and CDS
Overview

- Motivation for Clinical Decision Support (CDS)
- What is CDS today?
- Evidence for and against CDS
- What will CDS be tomorrow?
- Research Questions and Challenges
Carte Figurative des pertes successives en hommes de l'Armée Française dans la campagne de Russie 1812-1813 (1869)

Charles Joseph Minard's diagram of Napoleon's ill-fated march on Moscow
From Tufte, E. The Visual Display of Quantitative Information, p. 41
US Motivation for CDS

- Providers have incomplete knowledge of their patients
  - Patient data unavailable in 81% of cases in one clinic,
    - average of 4 missing items per case.
  - 18% of medical errors are due to inadequate availability of patient information.
  - Medicare beneficiaries see 1.3 – 13.8 unique providers annually, on average 6.4 different providers/yr

- Delayed translation of new knowledge to clinical practice
  - From bench to bedside, on average it takes > 17 years for new medical knowledge to be routinely applied in clinical practice

- Clinical Information Needs of Practitioners are unmet
  - Physicians in US urban and rural practices have on average more than 1 unanswered question per patient on optimal therapy diagnosis, or procedure
Clinical Information Exceeding Human Cognitive Capacity

Figure 1 Schematic contrasting human cognitive capacity (e.g., the number of sets of facts the brain can correlate in a decision) with the explosion of new biomedical data types. SNP indicates single nucleotide polymorphism. The authors adapted this figure with permission from Stead.⁵
The Quality of Health Care Delivered to Adults in the United States

Elizabeth A. McGlynn, Ph.D., Steven M. Asch, M.D., M.P.H., John Adams, Ph.D., Joan Keesey, B.A., Jennifer Hicks, M.P.H., Ph.D., Alison DeCristofaro, M.P.H., and Eve A. Kerr, M.D., M.P.H.

<table>
<thead>
<tr>
<th>ADA Guideline</th>
<th>Compliance</th>
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<tbody>
<tr>
<td>Measure blood pressure at every routine diabetes visit. 64.22%</td>
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<tr>
<td>Test for lipid disorders at least annually and more often if needed to achieve goals. 57.86%</td>
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<tr>
<td>Visual foot exam at every routine visit, comprehensive foot examination annually 44.92%</td>
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<tr>
<td>Test for microalbuminuria in all type 2 diabetic patients at least annually and during pregnancy. 23.62%</td>
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<tr>
<td>Dilated and comprehensive <strong>eye exam</strong> at diagnosis of Type 2 and annually. 14.21%</td>
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On average, Patients receive 54.9% of recommended care

"...The curse of medical education is the excessive number of schools. The situation can improve only as weaker and superfluous schools are extinguished."

“Society reaps at this moment but a small fraction of the advantage which current knowledge has the power to confer.”

Abraham Flexner, 
Medical Education in the United States and Canada. Boston: Merrymount Press, 1910
Net US could save $150B with HIT adoption, or approximately 7.5% of US Healthcare Expenditure

- The Value of Ambulatory Computerized Order Entry (ACPOE)
  - $44B US nationally; $29K per provider, per year

- The Value of HealthCare Information Exchange and Interoperability (HIEI)
  - $78B/yr

- The Value of IT-enabled Chronic Diabetes Management (ITDM)
  - $8.3B Disease Registries; Advanced EHR $17B

- The Value of Physician-Physician Tele-healthcare
  - >$20B*

- The Value of Personal Health Records
  - Approx. $20B

www.citl.org
Reforming health care
This is going to hurt
Achieve Adoption and Information Exchange through Meaningful Use of Health IT

Improve Care, Improve Population Health, and Reduce Health Care Costs through the Use of Health IT

Inspire Confidence and Trust in Health IT

Empower Individuals with Health IT to Improve their Health and the Health Care System

Achieve Rapid Learning and Technological Advancement

Beyond 2015: Transformed Health Care

Enhanced ability to study care delivery and payment systems

Empowered individuals and increased transparency

Improved care, efficiency, and population health outcomes

2011 – 2012: Data Capture and Sharing
- Accelerated adoption
- Data capture and exchange

2013 – 2014: Demonstrate Health System Improvement
- Widespread adoption and data exchange
- Process improvement

2015+: Transform Health Care and Population Health through Health IT
- Demonstrated improvements in care, efficiency, and population health
- Breakthrough examples of delivery and payment reform
A perfect storm for CDS?

- Lots of clinical data going online
  - Increasing std, interop
- Lots of genetic data coming
- Lots of personal/social data coming
- Lots of geospatial data coming
- Inexorable rise of Healthcare costs...
- Healthcare Reform
How do clinicians reason?

Formulating the Problem List: (Differential Diagnosis)

- Listen and Generate Hypotheses
- Cross-examine to gather data for hypothesis testing
- Evaluate Hypotheses
- Take action

Principles of DDx – Empirical Studies Reveal:

- Hypotheses are generated early
- Just a few active hypotheses under consideration at one time
- Bias and Cognitive Errors in differential diagnosis
  - Representativeness heuristic
    - Prior probability
    - Using clinical cues that do not accurately predict disease
    - Overcounting dependent predictors
    - Undercounting independent predictors
    - Mistaken use of regression toward the mean as evidence
    - Limited experience (few prior cases, or atypical)
  - Availability heuristic
  - Anchoring and Adjustment heuristics
Where 'x' = \[ p(T^+|D^-) \times U[D-A+] + (1 - p(T^+|D^-)) \times U[D-A-] - U[T] \]

'y' = \[ p(T^+|D^+) \times U[D+A+] + (1 - p(T^+|D^+)) \times U[D+A-] - U[T] \]

\[ p_1 = \text{no treatment - test threshold} \{ U[A^-] = U[T] \} \]

\[ p_2 = \text{test - treatment threshold} \{ U[T] = U[A^+] \} \]

Therefore,

\[ p_1 = \frac{\text{FPR} \times C - U[T]}{\text{FPR} \times C + \text{TPR} \times B} = \frac{p* \times (1 - \text{FPR})}{p* \times (1 - \text{FPR}) + (1 - p*) \times (1 - \text{TPR})} \]

\[ p_2 = \frac{(1-\text{FPR}) \times C + U[T]}{(1-\text{FPR}) \times C + (1 - \text{TPR}) \times B} = \frac{p* \times (1-\text{FPR})}{p* \times (1-\text{FPR}) + (1-p*) \times (1 - \text{TPR})} \]

if \[ U[T] \] is small.
The BMI Fundamental Theorem

Recall Blois’ Cognitive Funnel…
Behavior at the Entrance is the Key

Blois MS. Clinical Judgment and Computers
Humility

“I typed in your description of the symptoms. The computer says you have Dutch elm disease.”
“A knowledge-based system is an AI program whose performance depends more on the explicit presence of a large body of knowledge than on the presence of ingenious computational procedures...”

Inference Methods Used in Expert Systems

- Algorithmic
- Statistical
- Pattern Matching
- Rule-based (Heuristic)
- Fuzzy sets
- Neural nets
- Bayesian
- TBD...
The Evidence Cup Less than Half Full

- Brent James estimate of evidence-base to support current clinical practice
  - = 25%

- 75% of what we do not supported by evidence...

- Need for ‘real-time clinical epidemiology’: what have others done with patients like mine?
Knowledge is like a Cake-stack

If Braden Score < 11
→ Low Air Loss Bed, etc
If Abn Vasc Exam → Vascular Consult

Collections of Concepts –
Braden Assessment → Full Nursing Assessment
Collections of Orders – Order Sets

Med Orders, Special Beds, Topicals
Consults - Neurology or Vascular

Dorsalis Pedis Pulse → Present or Absent
Posterior Tibial Pulse → Present or Absent
Color → Pink, Pale, or Rubor on Dependency
Ankle Brachial Index → range 0.7 → 1.0

Taxonomies of Problems such as
CAD, Diabetes, Peripheral Vascular DZ

Taxonomies of Terms such as
Skin Exam, Decub Ulcer, Pulse, Skin Turgor
What is CDS Today?

- Formatting
  - Results review, “pocket rounds” reports

- Interpreting
  - EKG, PFTs, Pap, ABG

- Consulting
  - QMR, DxPlain, Iliad, Meditel, Abd Pain, MI risk

- Monitoring
  - Alerts: Critical labs, ABx/Surgery, ADEs

- Critiquing
  - Vent mgmt, anesthesia mgmt, HTN Rx, Radiology test selection, Blood products ordering

- **Add**: Consumer ‘smart apps’
  - Diet, exercise, medication management, diabetes care, etc.

Kuperman GJ et al. J Hlth Info Mgmt (13)2, pg 81-96
Evidence Review for CDS

- Systematic Review of 97 studies
- Practitioner performance improved
  - Overall in 64% of studies
  - 40% of 10 diagnostic systems
  - 76% of 21 reminder systems
  - 66% of 29 drug dosing or prescribing systems
- Patient outcomes
  - Only 7 of 52 studies reported improvements
- Factors associated with success
  - Automated prompts vs. requiring users to activate the system
  - When authors were developers of the system.

The Evidence for CDS

- CDS yields increased adherence to guideline-based care, enhanced surveillance and monitoring, and decreased medication errors
  - *(Chaudhry et al., 2006)*

- CDS, at the time of order entry in a computerized provider order entry system can help eliminate overuse, underuse, and misuse.
  - *(Bates et al., 2003; Austin et al., 1994; Linder, Bates and Lee, 2005; Tierney et al., 2003)*

- For expensive radiologic tests and procedures this guidance at the point of ordering can guide physicians toward ordering the most appropriate and cost effective, radiologic tests.
  - *(Bates et al., 2003; Khorasani et al., 2003)*

- Showing the cumulative charge display for all tests ordered, reminding about redundant tests ordered, providing counter-detailing during order entry, and reminding about consequent or corollary orders may also impact resource utilization
  - *(Bates and Gawande, 2003; Bates, 2004; McDonald et al., 2004).*
Koppel R et al. JAMA 293:10, Mar 2005

- Studied how CPOE can facilitate prescription error risk
- Survey research assessed users perceptions of risk
- Perception of users was that CPOE increased 22 types of medication error risks
22 Categories of Perceived Increased Medication Risk

- Information Errors
  - Assumed dose
  - Med d/c failure
  - Procedure-linked med error
  - Give now, and prn d/c error
  - Antibiotic renewal
  - Diluent option error
  - Allergy display
  - Conflict or duplicate med

- HCI/Workflow Errors
  - Patient selection
  - Med selection
  - Unclear log on/off
  - Meds after surgery
  - Post surgery suspended meds
  - Time/data loss when CPOE down
  - Med delivery error
  - Timing errors
  - Delayed nursing documentation
  - Rigid system design

Koppel R et al. JAMA 293:10, Mar 2005
Types of Unintended consequences

Frequency(%)

- work for clinicians: 19.8
- unfavorable workflow issues: 17.6
- never ending system demands: 14.8
- problems related to paper persistence: 10.8
- untoward changes in communication patterns and practices: 10.1
- negative emotions: 7.7
- generation of new kinds of errors: 7.1
- unexpected changes in the power structure: 6.8
- overdependence on the technology: 5.2

Campbell EM, Sittig DS et al., JAMIA 2006
Three from Kawamoto 2005 review are confirmed as key:
- Automatic provision of decision support as part of clinician workflow
- Provision of decision support at time and location of decisionmaking
- Provision of a recommendation, not just an assessment

Meta-analysis identified four additional
- Integration with charting or order entry system to support workflow integration
- Promotion of action rather than inaction
- No need for additional clinician data entry
- Local user involvement in the development process

Note: 15 (11.5%) of studies reviewed included all 7 factors
The future is here... it is just not evenly distributed*...


...a 2006 systematic review in *Annals of Internal Medicine* found that 25% of all studies on CDS took place at the above four institutions.

*William F. Gibson The Economist, Dec. 4, 2003
It’s Coming... CDS and Big Data
The Quantified Self

http://bit.ly/xMDwm2
Genetics, Incidentalomes, and Patient Preferences

- Sensitivity 100%, FPR 0.01%
- 10,000 tests > 60% with a FP test result
- What should we tell patients?
- What will patients want to know?

Goal: To assess, define, demonstrate, and evaluate best practices for knowledge management and clinical decision support in healthcare information technology at scale – across multiple ambulatory care settings and EHR technology platforms.

Significance: The CDS Consortium will carry out a variety of activities to improve knowledge about decision support, with the ultimate goal of supporting and enabling widespread sharing and adoption of clinical decision support.
An external repository of clinical content with web-based viewer

Search Criteria

Content Type...

Specialty
Toward a National Knowledge Sharing Service

CDS Consortium

Mid-Valley IPA (NextGen)
Salem, Oregon

Kaiser Roseville
UC Davis
Kaiser Sacramento
Kaiser San Rafael
Kaiser San Francisco
California

Wishard Hospital
Indianapolis, IN

Children's Hospital
Colorado

Cincinnati Children's
Nationwide Children's
Ohio

PECARN TBI CDS
CDS Grand Challenges

- Summarize patient-level information
- Prioritize recommendations to users
- Combine recommendations for patients with co-morbidities
- Improve the human-computer interface
- Use free text information in clinical decision support
- Manage large clinical knowledge databases
- Create an internet-accessible, clinical decision support repository
- Prioritize CDS content development and implementation
- Disseminate best practices
- Create an architecture for sharing executable CDS modules
- Mine large clinical databases to create new CDS

Sittig et al., J Bio Inf 2008
'Decision Cells' standardized and validated reusable building blocks of HIT modules and functions

Effective Use of PCS in Health IT

Reference Standards and Architecture

Patient-centered Data Abstractions and Knowledge Engineering

Cognitive and Behavioral Foundations

expression

‘Decision Proteins’ Essential codes and structure for key data, well specified software methods and open source code, APIs

translation

‘Decision RNA’ of abstract patient state definitions, knowledge objects, controlled terminology, ontology

transcription

‘Decision DNA’ of concepts, mental models, utilities, preferences, perception, and behavior

Feedback: PCS intervention efficacy

Feedback: localization, workflow, functionality

Feedback: portability, adaptability

Feedback: case variant, atypical

Feedback: functional expectation mismatch

Feedback: semantic constraints

Feedback: data, lexical, ontological variants

Feedback: knowledge engineering efficiency

Feedback: cognitive-objective discord

Feedback: coherence, understanding, self-determination, actualization
Clinicians, and Patients, are ill-equipped with the unaided mind to reason over the complexity and uncertainty of modern medicine.

.... Thus, CDS is an essential component of care.

Knowledge sharing is the only way to scale CDS.
The Nationwide Health Information Network

Mobilizing Health Information Nationwide

And knowledge!

The Internet

Standards, Specifications and Agreements for Secure Connections
“I conclude that though the individual physician is not perfectible, the system of care is, and that the computer will play a major part in the perfection of future care systems.”

Clem McDonald, MD NEJM 1976

Thank you!
Blackford Middleton, MD
bmiddleton1@partners.org
www.partners.org/cird