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T03 Knowledge-Based Decision-Support Systems for Implementing Clinical Practice Guideline

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  - PI: Mark Musen
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Opinions expressed are those of the speakers and not of the Department of Veteran Affairs and other funding agencies

Objectives

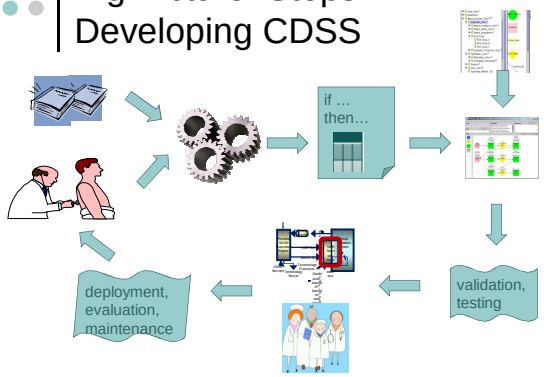
- Introduce the concept of knowledge-based clinical decision support systems (CDSS) for guideline-based care
- Understand the steps and issues involved in encoding guideline knowledge
- Describe alternative methods for representing computable clinical practice guidelines (CPGs)
- Outline the issues involved in deploying and integrating CDSS for guideline-based care

References to existing and emerging standards in CDS

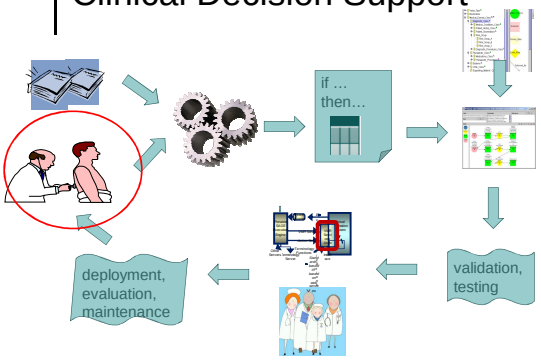
Course Outline

1. Introduction to clinical decision support
2. Clinical practice guidelines
3. Operationalization of guideline recommendations
4. Guideline modeling formalisms
5. Application of encoded guideline to patient
6. Implementation exercise
7. Socio-technical issues
8. Standards

Big Picture: Steps in Developing CDSS



Clinical Decision Support

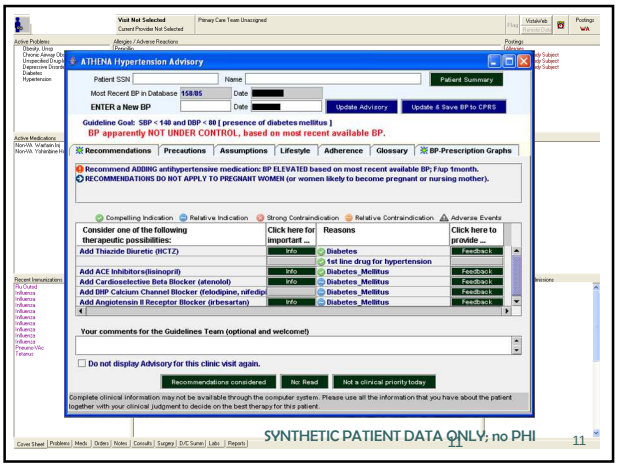


Clinical Decision-Support System

- Definition
  - "Any computer program designed to help health professionals make clinical decisions" (Musen 2006)
- Three types of CDSS
  - Tools for information management
  - Tools to focus attention
    - Check-list effect (Gawande 2009)
  - Tools to provide patient-specific recommendations

Example: ATHENA HTN CDS

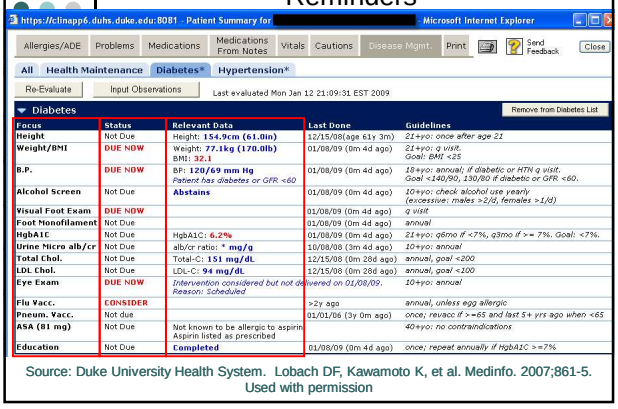
- Collaboration between Stanford and Veteran Affairs Palo Alto Health Care System
- Application of EON guideline model and technology *(Tu, 2001a)* to various clinical domains at VA (*Goldstein 2000, Michel 2008*)
- ATHENA-HTN deployed at multiple VA sites in California, North Carolina, & New England
- High level of physician usage



SYNTHETIC PATIENT DATA ONLY; no PHI

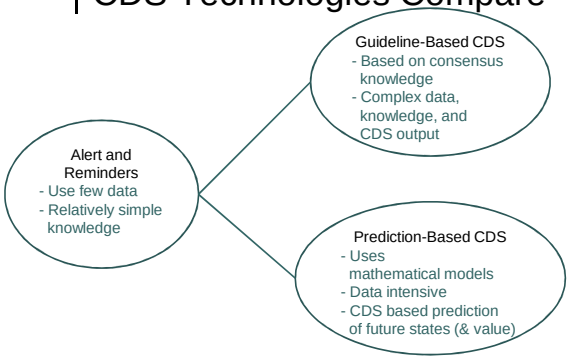
11 11

Example Disease Management Reminders

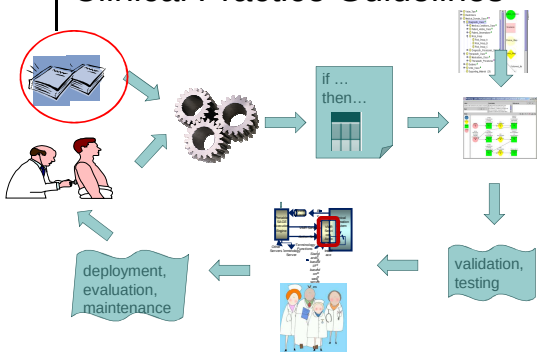


Source: Duke University Health System. Lobach DF, Kawamoto K, et al. Medinfo. 2007;861-5. Used with permission

How do Different Types of CDS Technologies Compare



Clinical Practice Guidelines



The "Quality Chasm"

- Institute of Medicine (IOM) report on *Crossing the Quality Chasm**
- Health care system must improve in
  - Patient safety, evidence-based practice
- Improvability gaps between best practices and actual practice
- Information technology (IT) can support quality improvement
  - But IT is underutilized in clinical setting

* *Crossing the Quality Chasm: A new health system for the 21st century*. National Academy Press, 2001

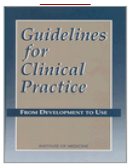
Quality Measurement and Improvement in Healthcare

- National Quality Forum (NQF) assembles healthcare experts to refine and endorse standards and measures. Link: www.qualityforum.org
- Linking quality indicators to health information technology systems
- Using quality indicators/performance measures as part of quality improvement

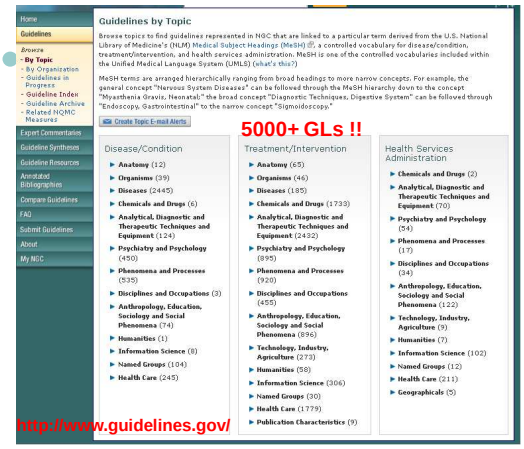
Literature Synthesis: Clinical Practice Guidelines

Intended to improve clinical practice
- summarize evidence
- recommend best practice
- reduce small area variation that is due to custom rather than to evidence-based differences in practice due to patient characteristics

- Newer forms of evidence syntheses



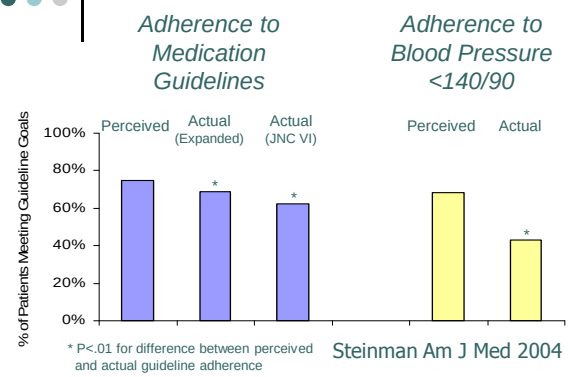
Field, M. J., K. N. Lohr, et al., Eds. (1992). Guidelines for Clinical Practice: From Development to Use. Institute of Medicine. Washington, D.C., National Academy Press.



Are Clinicians Aware of Their Own Performance?

- Clinicians not aware of their own rate of guideline adherence
  - From baseline data for ATHENA project
  - Steinman, M.A., M.A. Fischer, M.G. Shlipak, H.B. Bosworth, E.Z. Oddone, B.B. Hoffman, and M.K. Goldstein, *Clinician awareness of adherence to hypertension guidelines.* Am J Med, 2004. **117**(10): p. 747-54.

Perceived vs. Actual Guideline Adherence



* P<.01 for difference between perceived and actual guideline adherence

Steinman Am J Med 2004

What Does It Take To Change Practice?

- Changing physician practice requires more active steps than simply making guideline available
  - Lomas, J., G.M. Anderson, K. Domnick-Pierre, E. Vayda, M.W. Enkin, and W.J. Hannah, *Do Practice Guidelines Guide Practice? The effect of a consensus statement on the practice of physicians.* NEJM, 1989. **321**:1306-1311.
- Field of implementation research
  - Handbooks
    - Department of Veterans Affairs (VA) Health Services Research and Development (HSR&D)Implementation Guide: www.queri.research.va.gov/implementation
  - Journals
    - *Implementation Science*

Theoretical Model of the Path to Guideline Adherence

"Awareness to Adherence" model, in which the clinician must

- Become Aware of guideline
- Accept it
- Adopt it
- Adhere to it

Pathman, D. E., T. R. Konard, et al. (1996). "The Awareness-to-Adherence Model of the Steps to Clinical Guideline Compliance." Medical Care 34:873-889.

Many other conceptual models for influencing clinician behavior

Linking Informatics Support for Clinical Practice Guidelines to Theoretical Model

Step	*Facilitators*	*Informatics Support*
Aware	*Priming Activities* such as profiling of baseline performance	Profiling from pharmacy and diagnosis database
Accept	Active education such as Academic Detailing; Clinical Opinion Leaders	Present evidence relevant to patient; allow opinion leaders to browse knowledge
Adopt	*Enabling strategies* such as incorporation into clinic workflow	Integration with existing EMR
Adhere	*Reinforcing Strategies* such as reminders	Point-of-care patient-specific advisories

CDSS Only One of Many Steps to Improve Quality of Care!

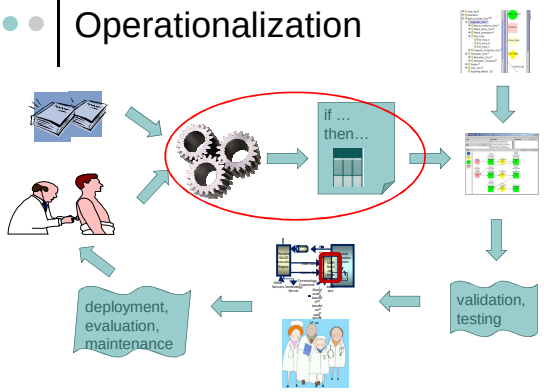
- Address the barrier of "forgetfulness" and human limits of information processing
  - McDonald, C. J. (1976). "Protocol-Based Computer Reminders, the Quality of Care and the Non-Perfectability of Man." New England Journal of Medicine **295**: 1351-1355.
- Early Understanding of when CDS is most effective:
  - patient-specific
  - delivered at point-of-care, that is arrive at the time of clinical decision making, rather than delayed
    - Tierney, W. M., S. L. Hui, et al. (1986). "Delayed Feedback of Physician Performance versus Immediate Reminders to Perform Preventive Care." Medical Care **24**: 659-666.
  - require a response
    - Litzelman, D. K., R. S. Dittus, et al. (1993). "Requiring Physicians to Respond to Computerized Reminders Improves their Compliance with Preventive Care Protocols." Journal of General Internal Medicine **8**: 311-317.

Recent Evidence Syntheses: Effect of Clinical Decision Support Systems

- CDS systems are effective at improving health care process measures across diverse settings, though evidence for efficiency outcomes remains sparse[1]
- On-screen point of care clinical reminders achieve improvements in provider behavior[2]
- CDS can improve care processes and patient health in chronic disease management and acute medical care[3,4]

1. Bright *Ann Intern Med* 2012
2. Shojania *Impl Sci* 2011
3. Roshanov *Impl Sci* 2011
4. Sahota *Impl Sci* 2011

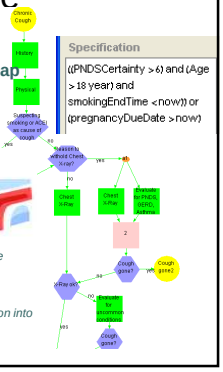
Operationalization



Encoding a Clinical Practice Guideline

Therefore, chest radiographs should be ordered before any therapy is prescribed in nearly all patients with chronic cough (Grade II-2). Chest radiographs do not have to be routinely obtained before beginning treatment for presumed PNDS in young nonsmokers, in pregnant women, or before observing the result of discontinuation of an ACEI.

Knowledge gap



Shiffman RN, Michel G, Essaihi A, Thornquist E. Bridging the Guideline Implementation Gap: A Systematic, Document-Centered Approach to Guideline Implementation. J Am Med Inform Assoc 2004;11(5):418-26.

Tu, S. W., Musen, M. A., et al (2004). Modeling Guidelines for Integration into Clinical Workflow. Medinfo 2004, San Francisco, CA, USA, 174-178.

Selection of Guideline Recommendations

- High impact
  - Recent clinical findings & evidence
  - Gap between best and usual practice
- Easily implementable
  - Available data
  - Clear criteria
  - Relative advantage of computer
    - e.g., calculating risk of CV event
    - e.g., visualization

Operationalize Recommendations

- Transform recommendations into computable format
  - Make implicit knowledge explicit
  - Make decision criteria evaluable against available data
- Examples
  - Beta blockers are indicated in all patients without a history of MI who have a reduced LVEF with no HF symptoms.
  - The combination of hydralazine and nitrates is recommended to improve outcomes for patients self-described as African-Americans, with moderate-severe symptoms of heart failure on optimal therapy with ACEIs, beta blockers, and diuretics.

2009 Focused Update: ACCF/AHA Guidelines for the Diagnosis and Management of Heart Failure in Adults, Circulation 2009;119:1977-2016.

Recommendations to Encode

Which BB?

Absence of contraindications?

Standard vocabulary? ICD9?

How to define? Below normal? Lower ?

Where in patient data? Standard vocabulary?

How to define? NYHA

How to define? Drug dose ranges?

- **Beta blockers** are indicated in all patients without a **history of MI** who have a **reduced LVEF** with **no HF symptoms**
- The combination of hydralazine and nitrates is recommended to improve outcomes for patients self-described as African-Americans, with **moderate-severe symptoms of heart failure** on **optimal therapy with ACEIs, beta blockers, and diuretics**.

Method to Create Encodable Knowledge

- Selection of guideline recommendations
- Augmentation
- Qualification
- Formalization of concepts
- De-abstraction
- Disambiguation
- Creating formal statements

Adapted from Shiffman 2004

Augmentation

Add missing details

Guideline text: "**Beta blockers** are indicated in all patients without a history of MI who have a reduced LVEF with no HF symptoms."

Added knowledge: Which of the beta blockers (e.g., atenolol, metoprolol, pindolol, etc.) is the formulary preferred drug?

Qualification

Make assumptions explicit

Text: "**Beta blockers** are indicated in all patients without a history of MI who have a reduced LVEF with no HF symptoms."

Implicit knowledge: absence of major Adverse Drug Event (ADE), contraindications

Explicit: **In the absence of major ADE or contraindications,** beta blockers are indicated…

Formalization of concepts

Add vocabulary codes, refine scope of terminology, add temporal constraints

Text: "heart failure"

Vocabulary codes: Diagnostic codes (ICD 9) or Medication codes

Refine scope: "… except diastolic heart failure"

Add temporal constraints: In the last 12 months

De-abstraction

Make abstract terms concrete for computation

Text: "**reduced LVEF**"

De-abstraction: LVEF <=40

Disambiguation

Clarify concepts with multiple interpretations and define mutually-exclusive values that can be measured

Text: "**optimal therapy with ACEIs, beta blockers, and diuretics**"

Disambiguation:

- Active prescriptions for *all* or *any* of ACE Inhibitor, beta blockers and diuretics?
- What is "optimal"? Need clarification from expert

Building Formal Statement

Translate narrative text into encodable statements

Text: "Beta blockers are indicated in all patients without a history of MI who have a reduced LVEF with no HF symptoms"

Formal: IF (absence of myocardial infarction) AND (LVEF <40) AND (absence of heart failure) AND (absence contraindications to beta blocker)

THEN recommend Beta blocker (atenolol)

Exercise!

ATP III content:

"For most patients with coronary heart disease and a baseline LDL cholesterol>=130mg/dL, an LDL lowering drug will be required to achieve an LDL cholesterol<100mg/dL."

Start by identifying the clinical concepts and applying the steps discussed earlier

Example

ATP III content:

"For most patients with coronary heart disease and a baseline LDL cholesterol>=130mg/dL, an LDL lowering drug will be required to achieve an LDL cholesterol<100mg/dL."

Formal statement

ATP III content:

"For most patients with coronary heart disease and a baseline LDL cholesterol>=130mg/dL, an LDL lowering drug will be required to achieve an LDL cholesterol<100mg/dL."

IF (Not taking LDL-lowering drug) AND (LDL cholesterol (LOINC code)>=130) AND (presence of CHD(ICD9 codes)) AND (absence of contraindications to statin) THEN recommend (Statin)

Exercise: Operationalizing a Clinical Practice Guideline

Exercise: Operationalizing a Clinical Practice Guideline

Third Report of the Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III) Full Report
Goal: Primary and secondary prevention of cardiovascular events
http://www.nhlbi.nih.gov/guidelines/cholesterol/atp3_rpt.htm
NIH Publication No. 02-5215; September 2002

ATP III Guidelines At-A-Glance: Quick Desk Reference
http://www.nhlbi.nih.gov/guidelines/cholesterol/dskref.htm
NIH Publication No. 01-3305; May 2001

Exercise Goals:

- **Learn process of transforming guideline text into a computable format**
- **Create knowledge to be encoded in a knowledge base**

I. Target population

Concept definition: Target population (ATP III)

"In all adults aged 20 years or older, a fasting lipoprotein profile (total cholesterol, LDL cholesterol, high density lipoprotein (HDL) cholesterol, and triglyceride) should be obtained once every 5 years."

Exercise: Using your own medical knowledge, try to define exclusion criteria (patients who should not receive DSS recommendations) based on patient data that would be available from a typical electronic medical record. Imagine criteria that are not explicit in the guideline recommendation.

II. Risk Determinants

Concept definition: Risk Groups (ATPIII Guideline)

Coronary Heart Disease (CHD) or CHD disease risk equivalent

"Identify presence of clinical atherosclerotic disease that confers high risk for coronary heart disease (CHD) events (CHD risk equivalent):

- *Coronary Heart Disease*
- *Diabetes*
- *Symptomatic carotid artery disease*
- *Peripheral arterial disease*
- *Abdominal aortic aneurysm*

Exercise: Define diabetes in a way that it can be queried from the EMR

III. Define Goals for therapeutic management in different risk categories

Concept definition: Goals (ATP III Guideline)

The Third Report of the Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III, or ATP III) focuses on the role of the clinical approach to prevention of coronary heart disease (CHD). This report continues to identify low-density lipoprotein (LDL) as the primary target of cholesterol-lowering therapy. Since ATP II, a number of controlled clinical trials with newer cholesterol lowering drugs have been reported. These trials demonstrated remarkable reductions in risk for CHD, in both primary and secondary prevention.

Table 4. Three Categories of Risk that Modify LDL Cholesterol Goals

Risk Category	***LDL Goal (mg/dL)***
CHD and CHD risk equivalents	*<100*
*Multiple (2+) risk factors**	*<130*
Zero to one risk factor	*<160*

Exercise: Define the goal for a patient with diabetes

IV. Define clinical algorithm defining output of DSS

Exercise: Define the clinical algorithm for patient with diabetes using simvastatin (lipid lowering agent)

Purpose: Sketch the clinical algorithm (draw a flowchart) that uses patient data to automatically generate patient specific recommendations.

Following is an excerpt from the guideline describing drug treatment.

> The usual drug will be a statin.
> The response to drug therapy should be checked in about 6 weeks.
> If the treatment goal has been achieved, the current dose can be maintained; if not, LDL-lowering therapy can be intensified, either by increasing the statin dose or by combining a statin with nicotinic acid.

What are possible recommendations would you like the DSS to generate?

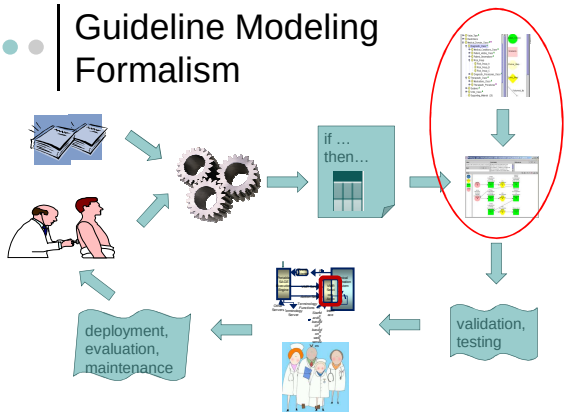
Sketch the clinical algorithm starting with patient eligibility. Include risk determination, goal setting, and initiation and intensification of drug treatment. Highlight decision points and decision options (actions).

For the sake of time, it is not necessary to include all patient scenarios. Model the following patient scenario: Patient is a 50-year old adult male with CDH and an active prescription for simvastatin. LDL-cholesterol is above goal level.

Extra Credit:

Define drug recommendation choices. What would you like the DSS to generate as drug recommendations?

Guideline Modeling Formalism



Course Outline

1. Introduction to clinical decision support
2. Clinical practice guidelines
3. Operationalization of guideline recommendations
4. Guideline modeling formalisms
   - Arden Syntax and Medical Logic Module
   - Knowledge model approach
5. Application of encoded guideline to patient
6. Implementation exercise
7. Socio-technical issues
8. Standards

Dimensions of Guideline Modeling Formalisms

- How is the CDS invoked?
- How are the data acquired and structured?
- What are the modeling primitives?
- How are decision criteria written?
- What interaction styles does it support?

Arden Syntax and Medical Logic Module

- An industry standard maintained by Health Level 7
- Organize decision knowledge as a collection of procedural rules (MLMs), written in Arden Syntax
- Each MLM designed to model knowledge required to make a single medical decision such as:
  - Contraindication alerts, management suggestions, data interpretations, treatment protocols, and diagnosis scores
- Can represent guidelines as a collection of MLMs *(Starren, 1994)*, but management of related MLMs a problem

Knowledge Slots: Execution Logic of MLM

How is CDS invoked?
- Data-driven trigger

```
<Knowledge>
    <Type>data-driven</Type>
    <Evoke>gentamicin_order;</Evoke>
    <Priority>50</Priority>
     <Data> creatinine_clearance := read last {creatinine_clearance } .... </Data>
     <Logic> if creatinine_clearance < 30 then
       calc_daily_dose := 3 * (0.05 + creatinine_clearance / 100) ;
       ordered_daily_dose   := periodic_dose * periodic_interval/(1 day) ;
       if (abs(ordered_daily_dose - calc_daily_dose)/calc_daily_dose > 0.2) then
         conclude true ;  endif ;  endif ;  </Logic>
    <Action>
      write  "Due to renal insufficiency, the dose of gentamicin " ||
            "should be adjusted. A single dose of " ||
            calc_daily_dose || " mg should be given, ]]>
    </Action>
    <Urgency>50</Urgency>
  </Knowledge>
```

Knowledge Slots: Execution Logic of MLM

How are data acquired &structured?
- Assignment to variables using "curly-braces" query into EHR

```
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```

What are the modeling primitives?
-Procedural statements
-Computer program-like expressions
How are decision criteria written?
- String syntax or XML

Knowledge Slots: Execution Logic of MLM

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      write  "Due to renal insufficiency, the dose of gentamicin " ||
            "should be adjusted. A single dose of " ||
            calc_daily_dose || " mg should be given, ]]>
    </Action>
    <Urgency>50</Urgency>
  </Knowledge>
```

What interaction style does it support?
- Push messages to user

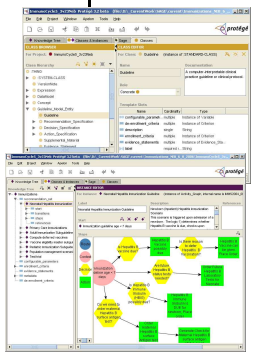
Knowledge Model Approach to Encoding Guidelines

- Guideline Model
  - Computable representation of guideline recommendations
  - e.g. goals, risk categories, tasks (decisions, actions)
  - Often uses graphical networks to represent flow of guideline tasks
- Numerous modeling formalisms for representing guidelines
  - e.g., EON, PRO*forma*, PRODIGY, GLIF, Asbru, GUIDE (Peleg 2003)
  - Make different design choice for representing guidelines
- Recurrent issue: Standardization

Two Example Formalisms: EON & PRO*forma*

- EON
  - National Library of Medicine funded project at Stanford
  - Uses Protégé knowledge-engineering environment to facilitate encoding of guidelines and protocols
  - The guideline modeling & execution technology used in ATHENA
- PRO*forma*: to be introduced later

EON Guideline Model and Modeling Environment



- Guideline model and instances created in Protégé
- Guideline model represented as a collection of classes and relationships among them
- Encoding a guideline (e.g. immunization guideline) means creating instances of these classes
- Protégé provides tool to specify guideline recommendations as directed graphs

Dimensions of Guideline Modeling Formalisms

- How is the CDS invoked?
- How are the data acquired and structured?
- How are decision criteria written?
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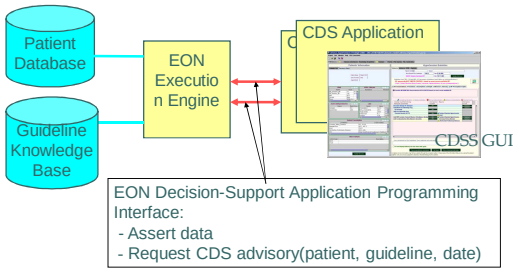
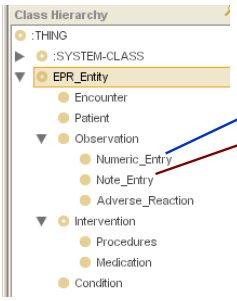
How is the CDS Invoked?



Structuring Patient Data

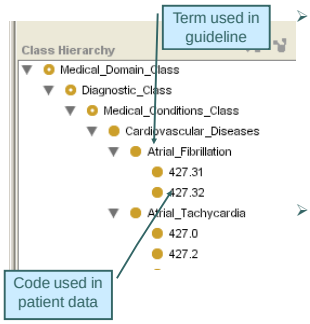
- Clinical statements about patient
  - "Patient 1 has diabetes"
  - "Patient 1's LDL cholesterol was 170mg/dl on 02/14/2006"
  - "Patient 1 is taking **lisinopril 20 mg/day** "
- Some high-level components:
  - Patient ID
  - Structured data element
  - Value
  - Drug name
  - Drug dose
  - Time-stamp

Patient Data Model



	Numeric entry	Note entry
Patient ID	Patient 1	Patient 1
Concept/Code	LDL (LOINC 4253)	Diabetes (ICD9 250.0)
Value	170	blank
Time-stamp	02/14/2006 2PM	05/05/2001 3PM

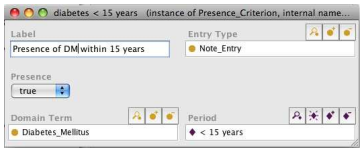
How Are Concepts Defined?



- Taxonomic hierarchy
  - Defines concepts used in guidelines
  - Maps guideline concepts to codes used in data
- Other CDS systems may use external terminologies

How are Decision Criteria Written?

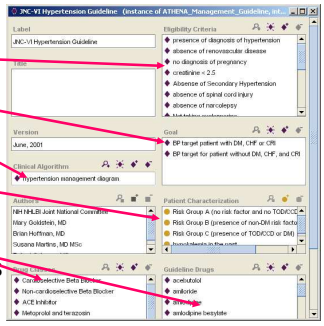
- Fill-in-blank templates to encode relatively simple expressions
- Other expression languages for complex criteria



Presence of DM within the last 15 years

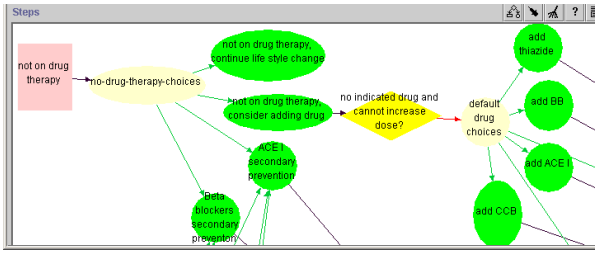
What Modeling Primitives are Available?

- Eligibility
- Goals
- Clinical algorithm
- Abstractions about patient
- Properties of treatment options

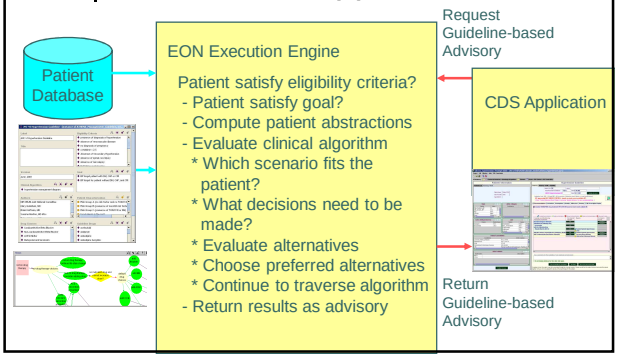


ATHENA HTN: Clinical Algorithm

- **scenario**, **decisions**, **action choices**



What Interaction Styles Does EON Support?

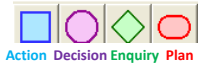


PRO*forma* Guideline Model

- Developed by Advanced Computation Laboratory, Cancer Research UK, J. Fox
- Tools (authoring & execution): Arezzo, Tallis
- Grounded in a logical model of decision making and plan enactment
- Use: CDSS routinely used in domains including HIV, cancer care and postoperative pain management *Sutton&Fox 2003; Fox &Das 2000*

The PRO*forma* GL model

- Main idea: a deliberately minimal set of modeling constructs (soundness, teaching)
- Tasks:



- All tasks share attributes describing goals, control flow (scheduling), preconditions, and post-conditions
- In the next slides, preconditions of tasks are displayed in blue on incoming arcs

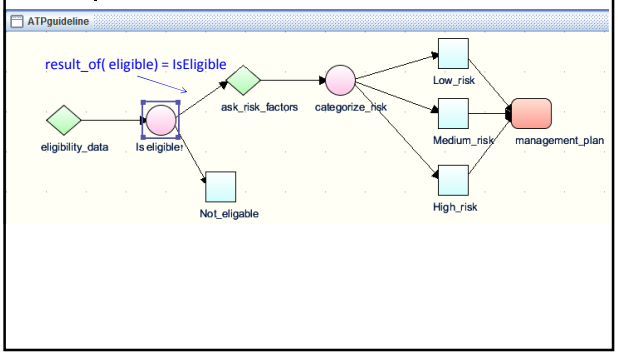
Is Eligible? PRO*forma* Decision

- Candidates: NotEligible, IsEligible
- Arguments: (for, against, confirm, exclude)

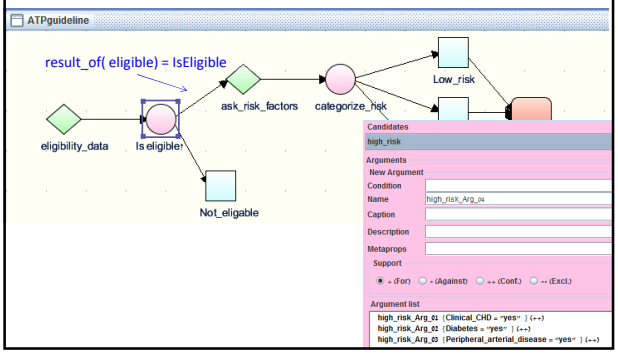
Candidate	Support	Condition
Eligible	For	Age>=18
Eligible	For	pregnancy= "no"
Candidate	**Support**	**Condition**
Not Eligible	Confirm	Age<18
Not Eligible	Confirm	pregnancy= "yes"

- Rules for recommending arguments
  - IsEligible: Netsupport >= 2
  - NotEligible: Netsupport >= 1

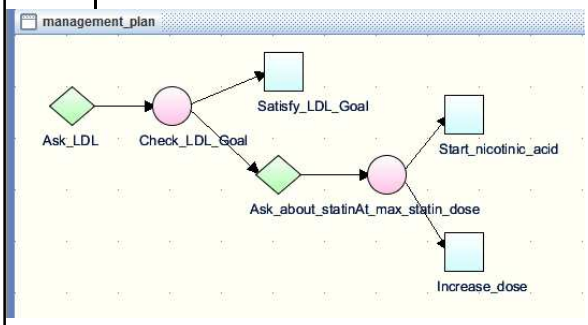
PRO*forma* Modeling: Tallis



PRO*forma* Modeling: Tallis

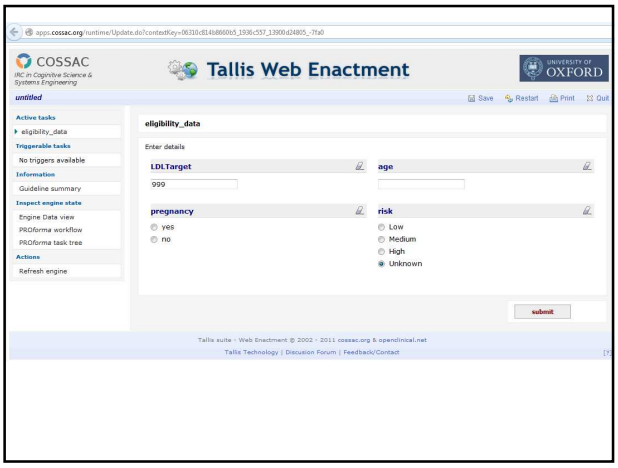


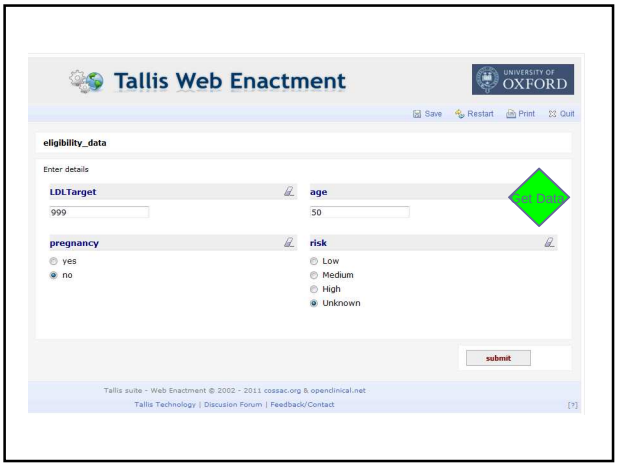
In-zooming of Management Plan



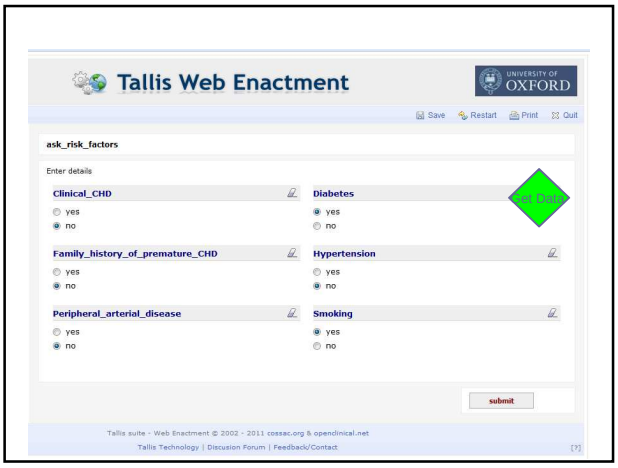
Tallis tool (web-based)

- Many thanks to Prof. John Fox and Dr. Vivek Patkar from Oxford University






Tallis Web Enactment
UNIVERSITY OF OXFORD
Save
Restart
Print
Quit
Is eligible?
Decision: Select the relevant intervention to link to arguments for and against
Candidates
IsEligible
Age > 18
Not pregnant
NotEligible
There are no applicable arguments for that candidate.
Decision
commit
Clinician may decide to choose the other alternative


Tallis Web Enactment
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ask_risk_factors
Enter details
Clinical_CHD
yes
no
Diabetes
yes
no
Family_history_of_premature_CHD
yes
no
Hypertension
yes
no
Peripheral_arterial_disease
yes
no
Smoking
yes
no
submit
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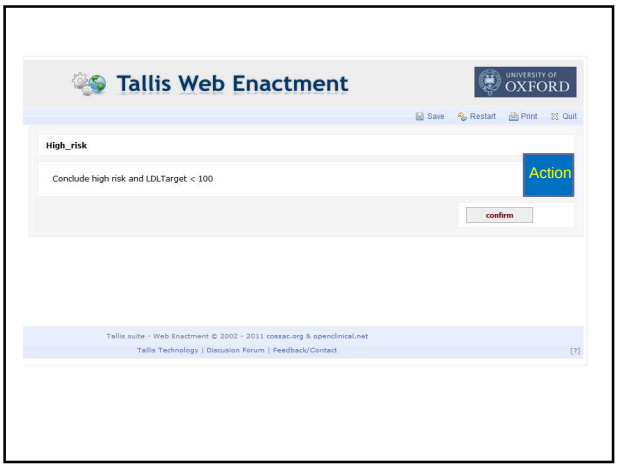
categorize_risk
Decision: Select the relevant intervention to link to arguments for and against
Candidates
high_risk
Diabetes
low_risk
Age > 45
Smoker
Diabetes = yes
medium_risk
Smoking
Diabetes
Age > 45
Decision
commit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High_risk
Conclude high risk and LDLTarget < 100
Action
confirm
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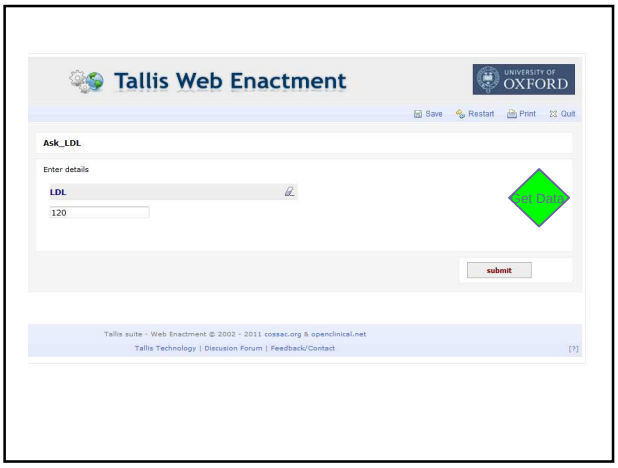
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Ask_LDL
Enter details
LDL
120
submit
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Check_LDL_Goal
Decision: Select the relevant intervention to link to arguments for and against
Candidates
Not_satisfy_LDL_Goal
LDL > = LDL target
Satisfy_LDL_Goal
There are no applicable arguments for that candidate.
Decision
commit
Tallis suite - Web Enactment © 2002 - 2011 cossac.org & openclinical.net
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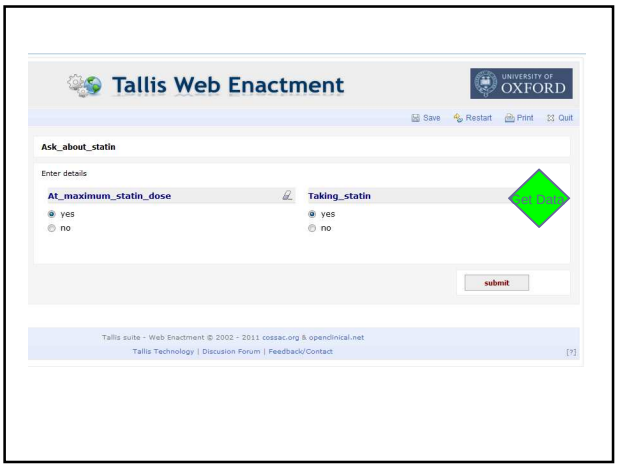
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Ask_about_statin
Enter details
At_maximum_statin_dose
yes
no
Taking_statin
yes
no
Test Data
submit
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Tallis Web Enactment
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Save
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Print
Quit
At_max_statin_dose
Decision: Select the relevant intervention to link to arguments for and against
Candidates
Start_nicotinic_acid
At_maximum_statin_dose = "yes"
Taking_statin = "yes"
Increase_statin_dose
Taking_statin = "yes"
Decision
commit
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Tallis Technology | Discusion Forum | Feedback/Contact
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Tallis Web Enactment
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Save
Restart
Print
Quit
Start_nicotinic_acid
Action
confirm
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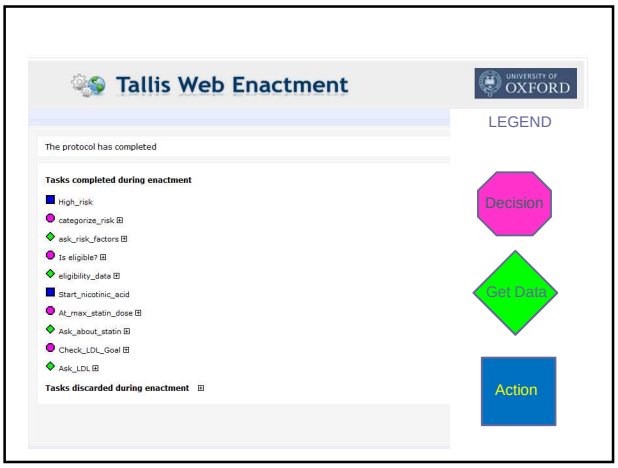


MP5

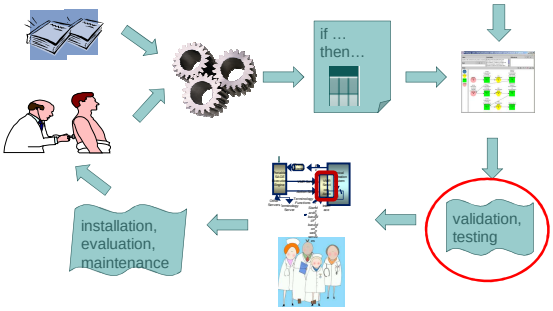
Discussion of differences between EON and PRO*forma*

- Ease of learning
  - How easy is it to learn the model semantics?
- Semantic elements
  - Can you answer the question: what are the eligibility criteria?
- Domain-specificity
  - Can you encode a guideline in a non-medical domain?

More information about guideline models and tools

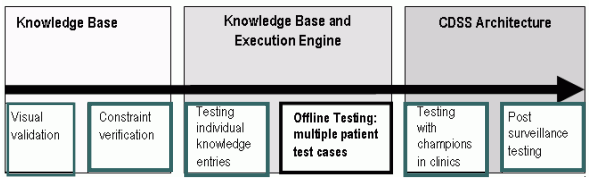
- …could be found at openclinical.org

Validation and Testing



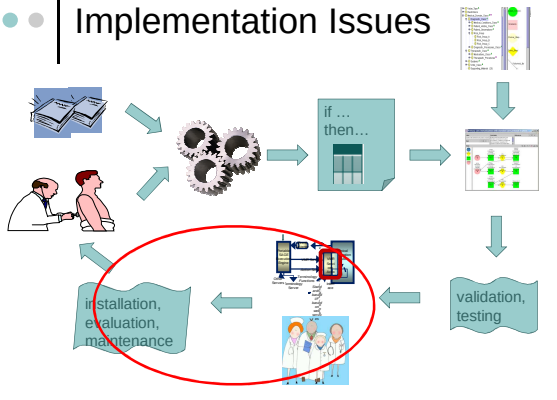
Step by Step Testing

Testing phases in the development of a CDSS



Martins, SB, Lai, S, Tu, S, Shankar, R, Hastings, SN, Hoffman, BB, et al. Offline testing of the ATHENA Hypertension decision support system knowledge base to improve the accuracy of recommendations. AMIA Annu Symp Proc 2006:539-43.

Implementation Issues



Implementation Exercise

Small group discussion (see next page for instruction)

Group discussion of the exercise

Implementation Exercise Handout:

Implementing the CDS system at a medical center, health care system, or office practice.

At this point, you have learned how to create a knowledge base of encoded clinical knowledge that can be linked to an execution engine to process individual patient data from an electronic health record (EHR) source to generate patient-specific recommendations for clinical management.

Let's next focus on implementing the system into an actual practice setting. Imagine that you have developed a free-standing system of the sort described above, and you now want to integrate it into the EHR in use at your medical center/institution. Think about what steps will need to be taken to accomplish this.

Form into small groups (approximately 4-6 people per group) and make sure that your group includes at least technical person and at least one clinician or administrator/manager. Working together as a group, answer the following questions:

1. Select a use case for the system running in your health care setting and describe it in simple terms. For example, you might choose something like "present patient-specific recommendations regarding hypertension management within the clinical workflow and the current EHR." Don't spend too much time on this step since it is just preparatory to the real work in the next steps.

2. Who are the stakeholders who need to be brought into the process?
    a. List the stakeholders by role (might be a department, a job title, or other indicator of role)
    b. Describe briefly what you need to ask of each stakeholder

3. What steps do you need to take to accomplish the implementation?
    a. Where would you start?
    b. Which steps would you do in sequence and which in parallel?
    c. Draw a rough timeline of the steps to implementation showing the major tasks (similar to a Gantt chart)

4. What do you see as (a) facilitators and (b) barriers to accomplishing the implementation?

Course Outline

1. Introduction to clinical decision support
2. Clinical practice guidelines
3. Operationalization of guideline recommendations
4. Guideline modeling formalisms
5. Application of encoded guideline to patient
6. Implementation exercise
7. Socio-technical issues
8. Standards

Knowing and Doing

"If to do were as easy as to know what were good to do, chapels had been churches and poor men's cottages princes' palaces."

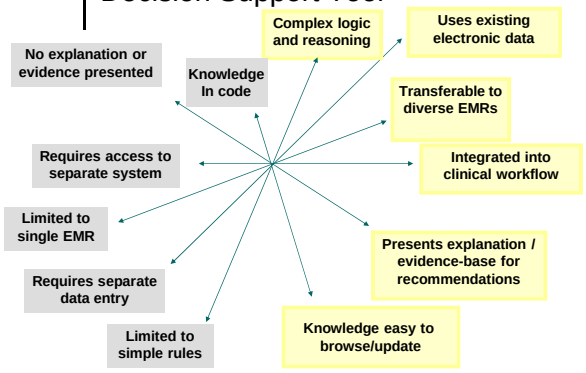
Portia, Act I, *Merchant of Venice*, Shakespeare

"Knowing is not enough; we must apply. Willing is not enough; we must do."

Goethe

From Evidence to Patient Care: Decision Support with Actionable Guidelines

Additional Dimensions of Decision Support Tool



Decision Support for Common Chronic Diseases

The physician often seen as wondering about a clinical question and then seeking out decision support:

The "Field of Dreams" approach to medical informatics implementations:

If you build it, they will come

Effects of CDSS - Earlier

- "Many CDSSs improve practitioner performance. To date, the effects on patient outcomes remain understudied and, when studied, inconsistent."

  Systematic review, Garg et al,JAMA, 2005
- "..a leading CPOE system often facilitated medication error risks…must attend to errors that these systems cause in addition to errors that they prevent…"
  - Koppel et al, JAMA, 2005

Recent Evidence Syntheses: Effect of Clinical Decision Support Systems

- CDS systems are effective at improving health care process measures across diverse settings, though evidence for efficiency outcomes remains sparse[1]
- On-screen point of care clinical reminders achieve improvements in provider behavior[2]
- CDS can improve care processes and patient health in chronic disease management and acute medical care[3,4]

1. Bright *Ann Intern Med* 2012
2. Shojania *Impl Sci* 2011
3. Roshanov *Impl Sci* 2011
4. Sahota *Impl Sci* 2011

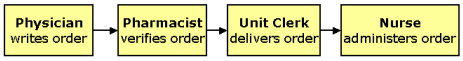
Addressing Human Factors Issues: Cognitive Tasks Analyses

- Observation of the initial use of CPOE in an intensive care unit
  - Actual workflow does not follow computer model
  - In 97 interruptions of RN to MD, 25% were reminders to enter computer orders

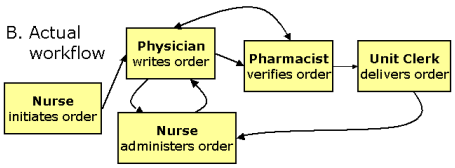
The effects of CPOE on ICU workflow. *CH Cheng, et al. AMIA Annu Symp Proc. 2003*

Entering and interpreting orders

A. CPOE conceptualization of workflow



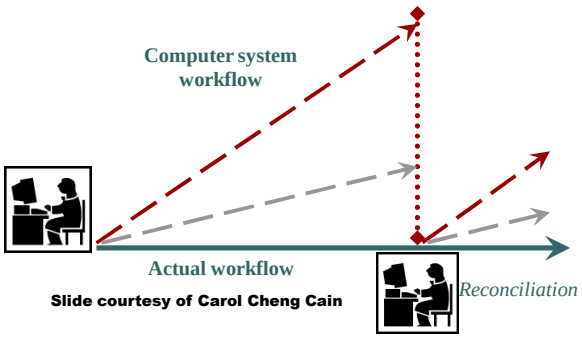
B. Actual workflow



In 97 interruptions of RN to MD, 25% were reminders

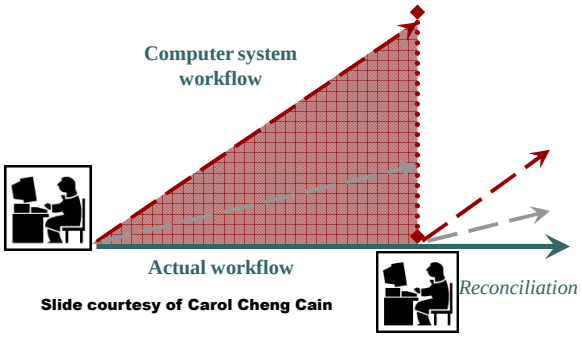
The effects of CPOE on ICU workflow. *CH Cheng, et al. AMIA Annu Symp Proc. 2003*

CPOE workflow should resemble actual workflow



Slide courtesy of Carol Cheng Cain

Computer system workflow diverges from actual workflow



Slide courtesy of Carol Cheng Cain

The Modern Problem of TMI

- "Too much information"
  - "…the Devil of Information Overload and his impish underlings the computer virus, the busy signal, the dead link…" (Gleick, *The Information*)
  - Reminder fatigue
  - Replicating chart notes
    - How to find the new info? How to review them all?
  - Displays with too many items to monitor, too many false alarms
    - Space shuttle, aviation

Designing for Safety

Computer systems can affect human problem solving and lead to errors/ unintended consequences

- **Data overload**
- **"automation surprises"**
- **Unobservable automated actions**
- **Missing data**
- **Inaccuracies in program inputs or logic**
- **Rearranging clinician priorities**
- **Generating false expectations**

- **Goldstein, M.K., B.B. Hoffman, R.W. Coleman, S.W. Tu, R.D. Shankar, M. O'Connor, S. Martins, A. Advani, and M.A. Musen, *Patient safety in guideline-based decision support for hypertension management: ATHENA DSS.* *JAMIA*, 2002. 9(6 Suppl): S11-6.**
- ***full text available through pubmedcentral***

Designing for People

Example design consideration:

When is that right time in the workflow to provide information?

Automatic vs deliberative modes of work

Goal for Developers

- Computers to do the things that computers do well
  - For example, search, retrieve, compare, count, compute logical algorithms
- To assist people, to free time for people to do what people do well
  - For example, interact with other people, detect emotional cues, weigh alternatives, communicate, make judgments about what to do

Socio-Technical

- Berg, M., *Rationalizing Medical Work: Decision-Support Techniques and Medical Practices*. Inside Technology, ed. W.E. Bijker, W.B. Carlson, and T. Pinch. 1997, Cambridge, Massachusetts: The MIT Press.
- Berg, M., *Patient care information systems and health care work: a sociotechnical approach.* Int J Med Inf, 1999. **55**(2): p. 87-101.

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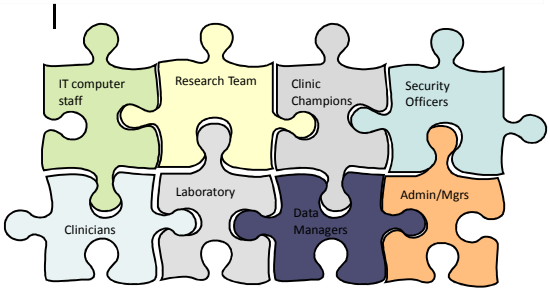
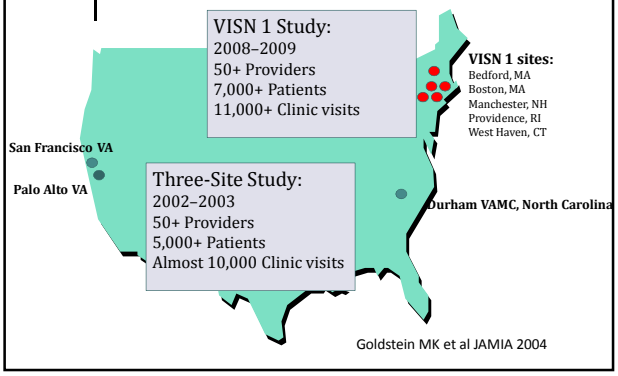
Working with Stakeholders: "SocioTechnical" Aspect



Berg, M. *Rationalizing Medical Work*. MIT Press 1997
Berg, M. Pt care info systems and health care work: a sociotechnical approach. *Int J Med Inform* 1999

ATHENA-HTN Multi-Site Studies



Goldstein MK et al JAMIA 2004

Recommendations

- Use a conceptual model to guide the implementation
  - Include stakeholders
- Design for Safety
- Test for usability
  - Include real-world settings
- Monitor after deployment

Course Outline

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8. Standards

Why Standards?

- Allows plug-and-play of components

Need for Standardizing Data Model

Observation
Code = BP
Value = 120/80 mmHg

Blood Pressure
Systolic = 120 mmHg
Diastolic = 80 mmHg

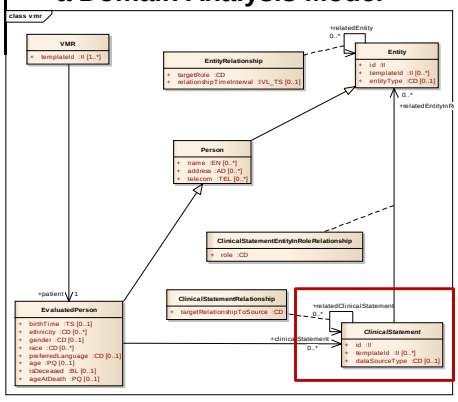
Observation
Code = BP
Observation
Code = SBP
Value = 120 mmHg
Observation
Code = DBP
Value = 80 mmHg

Vital Sign
Type = BP
Value = 120/80
Units = mmHg

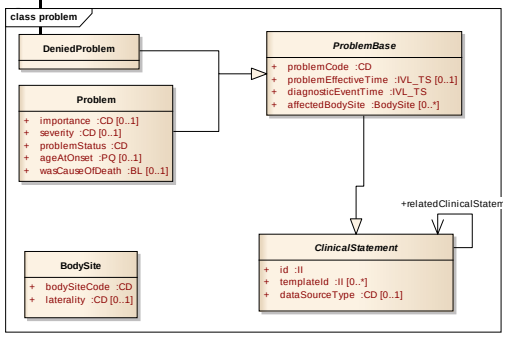
Health Level 7 Virtual Medical Record

- Virtual Medical Record (vMR)
  - Standardized information model for CDSS *(Johnson, 2001)*
  - Allows CDSS decision criteria to be formulated in terms standard queries
- Health Level 7 International
  - Standard developing organization
  - V3 Reference Information Model specifies the “grammar” of HL7 messages, including data type definitions
- Standard vMR being developed in HL7

HL7 vMR Balloted as a Domain Analysis Model



Example Clinical Statement



Standardization: GELLO

- Health Level 7 Standard expression language for decision support
- Expressive but complex
- No available standard implementation

Presence of Diabetes Mellitus within the last 3 months

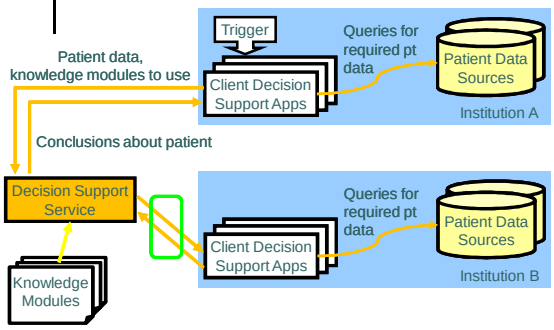
Let diabetes : CodedValue = Factory.CodedValue ("SNOMED-CT", "73211009")
…
Observation → exists(code.equal(finding) and value.implies(diabetes)
and effective_time.intersect(ThreeMonthsAgo, PointInTime.NOW()))

Sordo, M., Boxwala, A., Ogunyemi, O. and Greenes, R. (2004). *Description and Status Update on GELLO: a Proposed Standardized Object-oriented Expression Language for Clinical Decision Support*. Medinfo. 2004, 164-168

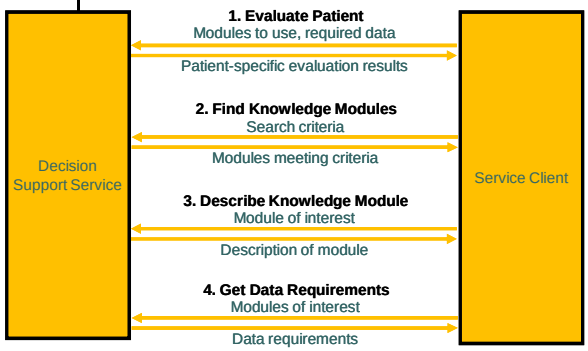
Standardization of Decision Support Service (DSS)

- Business purpose:
  - To facilitate implementation and maintenance of clinical decision support (CDS) applications
- Approach:
  - Evaluates patient data (inputs) using knowledge modules and returns machine-interpretable conclusions (outputs)
- Normative HL7/ANSI standard developed in collaboration with Object Management Group (OMG)

DSS – Architectural Overview



DSS – Primary Service Operations



Standard-Based CDS Deployment: OpenCDS

- Standard interfaces and data models
  - Reference implementation of HL7/OMG DSS interface
  - vMR data model
  - Data mappers (e.g., for CCD → vMR)
- Reference DSS knowledge management framework
  - JBoss Drools and associated authoring/knowledge management tools
  - Full-featured terminology support
  - Knowledge repository and knowledge sharing service
- DSS "wrappers" for other CDS engines

OpenCDS: http://www.opencds.org

Course Outline

1. Introduction to clinical decision support
2. Clinical practice guidelines
3. Operationalization of guideline recommendations
4. Guideline modeling formalisms
5. Application of encoded guideline to patient
6. Deployment of CDS
7. Socio-technical issues
8. Standards

Exercise: Operationalizing a Clinical Practice Guideline

Third Report of the Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III) Full Report
Goal: Primary and secondary prevention of cardiovascular events
http://www.nhlbi.nih.gov/guidelines/cholesterol/atp3_rpt.htm
NIH Publication No. 02-5215; September 2002

ATP III Guidelines At-A-Glance: Quick Desk Reference
http://www.nhlbi.nih.gov/guidelines/cholesterol/dskref.htm
NIH Publication No. 01-3305; May 2001

Exercise Goals:

- **Learn process of transforming guideline text into a computable format**
- **Create knowledge to be encoded in a knowledge base**

I. Target population

Concept definition: Target population (ATP III)

"In all adults aged 20 years or older, a fasting lipoprotein profile (total cholesterol, LDL cholesterol, high density lipoprotein (HDL) cholesterol, and triglyceride) should be obtained once every 5 years."

Exercise: Using your own medical knowledge, try to define exclusion criteria (patients who should not receive DSS recommendations) based on patient data that would be available from a typical electronic medical record. Imagine criteria that are not explicit in the guideline recommendation.

Answer:

Possible exclusions: Pregnancy and metastatic cancer should be exclusion criteria since the guideline does not deal with these populations. There should also be an upper bound on

II. Risk Determinants

Concept definition: Risk Groups (ATPIII Guideline)

Coronary Heart Disease (CHD) or CHD disease risk equivalent

"Identify presence of clinical atherosclerotic disease that confers high risk for coronary heart disease (CHD) events (CHD risk equivalent):

- *Coronary Heart Disease*
- *Diabetes*
- *Symptomatic carotid artery disease*
- *Peripheral arterial disease*
- *Abdominal aortic aneurysm*

Exercise: Define diabetes in a way that it can be queried from the EMR

Answer

Should it be type I or II?. Should you use ICD9 codes, procedure codes, medications, labs or a combination of these to define diabetes? How can you increase your specificity without limiting your sensitivity?

Miller et all, Diabetes Care, 2004

Criteria	Sensitivity	Specificity
Prescription for a diabetes medication In current year and/or 2+ codes for diabetes from outpatient or inpatient source in past 24 months	93%	98%
Any diagnostic code	78.3%	95.7%

III. Define Goals for therapeutic management in different risk categories

Concept definition: Goals (ATP III Guideline)

The Third Report of the Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III, or ATP III) focuses on the role of the clinical approach to prevention of coronary heart disease (CHD). This report continues to identify low-density lipoprotein (LDL) as the primary target of cholesterol-lowering therapy. Since ATP II, a number of controlled clinical trials with newer cholesterol lowering drugs have been reported. These trials demonstrated remarkable reductions in risk for CHD, in both primary and secondary prevention.

Table 4. Three Categories of Risk that Modify LDL Cholesterol Goals

Risk Category	***LDL Goal (mg/dL)***
CHD and CHD risk equivalents	*<100*
*Multiple (2+) risk factors**	*<130*
Zero to one risk factor	*<160*

Exercise: Define the goal for a patient with diabetes

Answer: For a patient with diabetes who would be characterized as a CHD risk equivalent, the LDL goal is <100mg/dL.

Goals are high level components of a guideline. Guidelines can have multiple goals each for a specific group of patients. Goals can also be used to assess how well a clinician's panel of patients is doing for quality improvement initiatives.

IV. Define clinical algorithm defining output of DSS

Exercise: Define the clinical algorithm for patient with diabetes using simvastatin (lipid lowering agent)

Purpose: Sketch the clinical algorithm (draw a flowchart) that uses patient data to automatically generate patient specific recommendations.

Following is an excerpt from the guideline describing drug treatment.

> The usual drug will be a statin.
> The response to drug therapy should be checked in about 6 weeks.
> If the treatment goal has been achieved, the current dose can be maintained; if not, LDL-lowering therapy can be intensified, either by increasing the statin dose or by combining a statin with nicotinic acid.

What are possible recommendations would you like the DSS to generate?

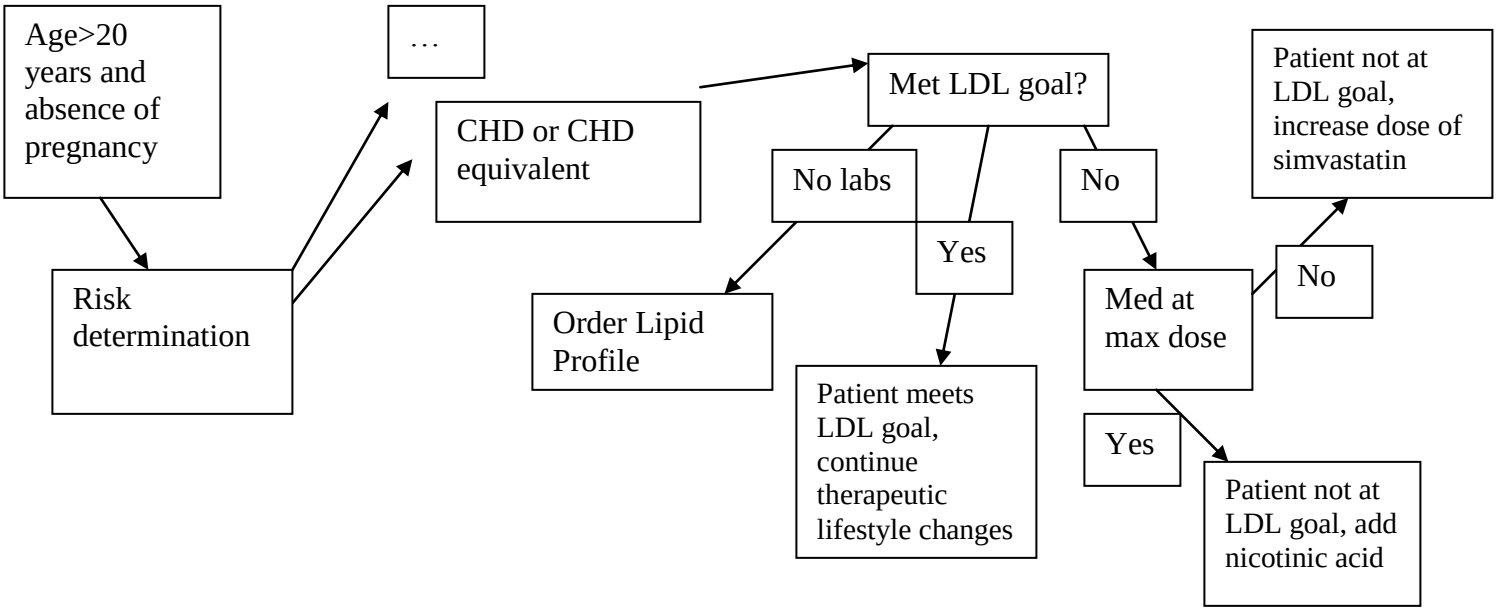
Sketch the clinical algorithm starting with patient eligibility. Include risk determination, goal setting, and initiation and intensification of drug treatment. Highlight decision points and decision options (actions).

For the sake of time, it is not necessary to include all patient scenarios. Model the following patient scenario: Patient is a 50-year old adult male with CDH and an active prescription for simvastatin. LDL-cholesterol is above goal level.

Answer: Suggestions of recommendations to generate:

- If LDL is past due then "Order lipid profile"
- If LDL<100 in valid window then "Patient meets LDL goal, continue therapeutic lifestyle changes"
- If LDL>=100 in valid window and dose of simvastatin is low then "Patient not at LDL goal, increase dose of simvastatin"
- If LDL>=100 in valid window and dose of simvastatin is maximized then "Patient not at LDL goal, add nicotinic acid"

Opreationalizing a Clinical Practice Guideline



Extra Credit:

Define drug recommendation choices. What would you like the DSS to generate as drug recommendations?

Answer: Design choices of DSS output will inform how you model drugs in knowledge base

- ✓ Will DSS recommend all drug classes for clinician to consider? Or will it prioritize and offer only one drug class?
- ✓ What level of granularity is best for drug recommendations?
    a) Drug class?
    b) Preferred drug?
    c) Preferred drug and dose?
- ✓ For each drug class need to define:
    a) Preferred drug (usually based on formulary and cost)
    b) Absolute contraindications
    c) Relative contraindications
    d) Compelling indications
    e) Relative indications
    f) Drug partners to avoid

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Guideline Clearing House: http://www.guidelines.gov/

Open Clinical: http://openclinical.org/

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A methodology for achieving consensus and disambiguation

Augmentation

Add missing details from other sources

Guideline text: "*In patients with hypertension and stable angina pectoris, the first drug of choice is usually a beta blocker…"*

Added knowledge: specific preferred drug

Qualification

Make assumptions explicit

Text: "In patients with hypertension and stable angina pectoris, the first drug of choice is usually a beta blocker..."

Implicit knowledge: absence of major Adverse Drug Event (ADE)

Explicit: **In the absence of major ADE,** in patients with hypertension and ….

Formalization of concepts

Add vocabulary codes, refine scope of terminology, add temporal constraints

Text: "diabetes"

Vocabulary codes: Diagnostic codes (ICD 9) / Medication codes

Refine scope of terminology: "… except gestational diabetes"

Standard vocabularies:
- Diseases- ICD9 codes
- Laboratory- LOINC codes
- Drugs- National Formulary

De-abstraction

De-abstract terms that are too abstract for computation

Text: "high cardiovascular risk"

De-abstraction: Framingham 10 yr risk score >=15

Text: "recent myocardial infarction"

De-abstraction: myocardial infarction within 4 weeks

Disambiguation of concepts

Create concepts with mutually-exclusive values that can be measured

Text: Duration could be frequent or ≥2 times per week

Disambiguation: Duration could be 0-1 times per week or ≥2 times per week

Building formal statements

Translate narrative text into statements closer to computable formats

Text: "In patients with post myocardial infarction, ACEIs, …most beneficial."

"ACEIs favorably affect the progression of diabetic nephropathy…"

Formal: e.g., IF (presence of (post myocardial infarction OR diabetic nephropathy))
THEN (recommend) ACEI