Decision Support for the Learning Health System: *Shoring up the “effector arm”*

Mark A. Musen  
Stanford University School of Medicine  
Stanford, California  
USA
The Learning Heath System

In a learning health care system, research influences practice and practice influences research.

**Implement**
Apply the plan in pilot and control settings.

**Evaluate**
Collect data and analyze results to show what does and does not work.

**Adjust**
Use evidence to influence continual improvement.

**Disseminate**
Share results to improve care for everyone.

**Internal and External Scan**
Identify problems and potentially innovative solutions.

**Design**
Design care and evaluation based on evidence generated here and elsewhere.

We know how to apply rules really well ...

• Drug–drug interactions
• Contraindicated drugs
• Abnormal laboratory results
• Opportunities for immunizations or preventive services
• And other relationships between specific situations and specific actions
But we continue to look for our keys where the light is

• We seek out decision-support opportunities that are amenable to rule-based solutions
• We are not addressing the complex decision-support challenges required by an aging population that faces
  – Multimorbidity
  – Polypharmacy
  – Lack of clinical-trial evidence on which to base care
• We have not mapped out the effector arm of an integrated learning health system
JNC VII Guideline for Management of Hypertension

Lifestyle Modifications

Not at Goal Blood Pressure (<140/90 mmHg) (<130/80 mmHg for those with diabetes or chronic kidney disease)

Initial Drug Choices

Without Compelling Indications

Stage 1 Hypertension (SBP 140–159 or DBP 90–99 mmHg) Thiazide-type diuretics for most. May consider ACEI, ARB, BB, CCB, or combination

Stage 2 Hypertension (SBP ≥160 or DBP ≥100 mmHg) Two-drug combination for most (usually thiazide-type diuretic and ACEI, or ARB, or BB, or CCB)

With Compelling Indications

Drug(s) for the compelling indications (see table 12) Other antihypertensive drugs (diuretics, ACEI, ARB, BB, CCB) as needed

Not at Goal Blood Pressure

Optimize dosages or add additional drugs until goal blood pressure is achieved. Consider consultation with hypertension specialist.

ACEI, angiotensin converting enzyme inhibitor; ARB, angiotensin receptor blocker; BB, beta blocker; CCB, calcium channel blocker; DBP, diastolic blood pressure; SBP, systolic blood pressure
Blood Pressure apparently not under control:
Based on last measurement of 145/92 taken 87 days ago on mm/dd/yyyy

CARDIO RISK FACTOR: 23% High

*Estimated 10 Year cardiovascular risk factor for this patient

Recommendations:
- Consider intensifying drug treatment: BP Elevated based on most recent available BP
- There appears to be a Strong Contraindication to a currently prescribed drug, evaluate clinical significance
- Bronchospasm is a Strong Contraindication or use of beta adrenergic receptor antagonists, although many patients tolerate and therefore benefit from this drug therapy

Review lifestyle modifications with the patient. See the Lifestyle page.

Therapeutic Possibilities:
- Discontinue atenolol
- AND start one of the following drugs
  - ACE Inhibitors (lisinopril)
  - (non-DHP) Calcium Channel Blocker (diltiazem)
- Add one or more of the following drugs
  - ACE Inhibitors (lisinopril)
  - (non-DHP) Calcium Channel Blocker (diltiazem)
- Increase dosage of hydrochlorothiazide
ATHENA is driven by coded EHR data

Consider adding an ACE Inhibitor because of a compelling indication (heart failure)
ATHENA needs a knowledge base ...

• That captures guideline knowledge in a holistic manner
• That can enable the computer to build a comprehensive model of the patient situation
• That can lead to suggestions for treatment that are predicated on past responses to treatment
• That clinicians themselves can
  – Understand
  – Edit
  – Debug
ATHENA needs a knowledge base ...

• That captures guideline knowledge in a holistic manner
• That can enable the computer to build a comprehensive model of the patient situation
• That can lead to suggestions for treatment that are predicated on past responses to treatment
• That clinicians themselves can
  – Understand
  – Edit
  – Debug
What Is Ontology?

• The study of being
• A discipline co-opted by computer science to enable the explicit specification of
  – Entities
  – Properties and attributes of entities
  – Relationships among entities
What Is Ontology?

• The study of being
• A discipline co-opted by computer science to enable the explicit specification of
  – Entities
  – Properties and attributes of entities
  – Relationships among entities

And health care has lots of ontologies!
SNOMED Clinical Terms

- Body structure
- Clinical finding
- Environment or geographical location
- Event
- Linkage concept
- Observable entity
- Organism
- Pharmaceutical / biologic product
- Physical force
- Physical object
- Procedure
  - Administrative procedure
  - Blood bank procedure
  - Community health procedure
  - Determination of information related to transfusion
  - Environmental care procedure
  - General treatment
  - Laboratory procedure
  - Nuclear medicine procedure
  - Obstetric procedure
  - Outpatient procedure
  - Patient encounter procedure
  - Preoperative/postoperative procedures
  - Procedure by intent
  - Procedure by method
  - Procedure by priority
  - Procedure by site
  - Procedure categorized by device involved
  - Procedure in coronary care unit
  - Procedure related to anesthesia and sedation
  - Procedure related to breastfeeding
  - Procedure with a clinical finding focus
  - Procedure with a procedure focus
  - Procedure on ganglion cyst
  - Procedure on site
  - Procedure on procedure focus
  - Procedures related to eating and drinking
  - Social service procedure
  - Regimes and therapy
  - Staff related procedure
  - Determination of information related to transfusion
  - Procedure in coronary care unit
  - Procedures relating to mobility
  - Administrative procedure
  - Outpatient procedure
  - Procedure categorized by device involved
  - Procedure in coronary care unit
  - Procedure related to anesthesia and sedation
  - Procedure related to breastfeeding
  - Procedure with a clinical finding focus
  - Procedure with a procedure focus
  - Procedure on ganglion cyst
  - Procedure on site
  - Procedure on procedure focus
  - Procedures related to eating and drinking
  - Social service procedure
  - Regimes and therapy
  - Staff related procedure
For Class: Management_Guideline (instance of :STANDARD-CLASS)

Name: Management_Guideline

Documentation:
Management guidelines model decisions and actions that lead to dependent changes in patient states over time. A management guideline has one main clinical algorithm (Management Diagram).

Role: Concrete

Template Slots:

<table>
<thead>
<tr>
<th>Name</th>
<th>Cardinality</th>
<th>Type</th>
<th>Other Facets</th>
</tr>
</thead>
<tbody>
<tr>
<td>alternative_goals</td>
<td>multiple</td>
<td>Instance of Goal</td>
<td></td>
</tr>
<tr>
<td>assume_if_no_goal_v...</td>
<td>single</td>
<td>Symbol</td>
<td>allowed-values={make_alternative...}</td>
</tr>
<tr>
<td>authors</td>
<td>multiple</td>
<td>String</td>
<td></td>
</tr>
<tr>
<td>clinical_algorithm</td>
<td>required</td>
<td>Instance of Management_G...</td>
<td></td>
</tr>
<tr>
<td>eligibility_criteria</td>
<td>multiple</td>
<td>Instance of Criterion</td>
<td></td>
</tr>
<tr>
<td>goal</td>
<td>multiple</td>
<td>Instance of Conditional_G...</td>
<td></td>
</tr>
<tr>
<td>label</td>
<td>required</td>
<td>String</td>
<td></td>
</tr>
<tr>
<td>patient_characterization</td>
<td>multiple</td>
<td>Instance of Diagnostic_T...</td>
<td></td>
</tr>
<tr>
<td>references</td>
<td>multiple</td>
<td>Instance of Supporting_M...</td>
<td></td>
</tr>
<tr>
<td>subguidelines</td>
<td>multiple</td>
<td>Instance of Management_G...</td>
<td></td>
</tr>
<tr>
<td>title</td>
<td>single</td>
<td>String</td>
<td></td>
</tr>
<tr>
<td>version</td>
<td>single</td>
<td>String</td>
<td></td>
</tr>
</tbody>
</table>
**Title**

The clinical information from this system is advisory only and is intended to supplement the knowledge of health care professionals regarding the management of hypertension. It is not intended to replace sound clinical judgment or individualized patient care in delivery of healthcare services.

**Authors**

- NIH NHLBI Joint National Committee
- Mary Goldstein, MD
- Brian Hoffman, MD
- Susana Martins, MD MSc

**Version**

February, 2009

**Eligibility Criteria**

- presence of diagnosis of hypertension
- absence of renovascular disease
- no diagnosis of pregnancy
- Absence of Secondary Hypertension
- absence of spinal cord injury

**Clinical Algorithm**

- hypertension management diagram

**Goal**

- BP target patient with diabetes mellitus
- BP target for patient without diabetes mellitus

**Patient Characterization**

- Risk_Group_A
- Risk_Group_B
- Risk_Group_C
- Home_BP

**Drug Usages**

- ACE_Inhibitors
- Alpha_beta_blockers
- Alpha_blockers
- Angiotensin_II_receptor_blockers
- Beta-Blockers-Cardioselective
- Beta-Blockers-non-cardioselective

**Guideline Drugs**

- acebutolol
- amiloride
- amloidine
- amloidine besylate
- atenolol
- cartopril
**Recommendations**

- **Blood Pressure apparently not under control:** Based on last measurement of 145/92 taken 87 days ago on mm/dd/yyyy

**Cardio Risk Factor: 23% High**

*Estimated 10 Year cardiovascular risk factor for this patient*

**Recommendations**

- Consider intensifying drug treatment: **BP Elevated** based on most recent available BP
- There appears to be a **Strong Contraindication** to a currently prescribed drug, evaluate clinical significance
- Bronchospasm is a **Strong Contraindication** or use of beta adrenergic receptor antagonists, although many patients tolerate and therefore benefit from this drug therapy

**Therapeutic Possibilities**

- **Discontinue** atenolol
- **AND start one of the following drugs**
  - ACE Inhibitors (lisinopril)
  - (non-DHP) Calcium Channel Blocker (diltiazem)
- **Add one or more of the following drugs**
  - ACE Inhibitors (lisinopril)
  - (non-DHP) Calcium Channel Blocker (diltiazem)
- Increase dosage of hydrochlorothiazide

**Indications**

- Heart Failure
- CKD

**Contraindications**

- Brochospastic disease
- Heart Failure

**Blood Pressure and Prescription History**

- **142/90 on**

**Lisinopril**

- **80 MG**
- **5 MG**
- **100 MG**
- **80 MG**
- **5 MG**
- **100 MG**

**Showing 7 of 10 drugs.**

**Do you have feedback for the Research team?**

Thank you!

**Exit**
Management Guideline

Management guidelines model decisions and actions that lead to dependent changes in patient states over time. A management guideline has one main clinical algorithm (Management Diagram).

Template Slots

<table>
<thead>
<tr>
<th>Name</th>
<th>Cardinality</th>
<th>Type</th>
<th>Other Facets</th>
</tr>
</thead>
<tbody>
<tr>
<td>alternative_goals</td>
<td>multiple</td>
<td>Instance of Goal</td>
<td></td>
</tr>
<tr>
<td>assume_if_no_goal_v...</td>
<td>single</td>
<td>Symbol</td>
<td>allowed-values=(make_alternative_...)</td>
</tr>
<tr>
<td>authors</td>
<td>multiple</td>
<td>String</td>
<td></td>
</tr>
<tr>
<td>clinical_algorithm</td>
<td>required</td>
<td>Instance of Management_...</td>
<td></td>
</tr>
<tr>
<td>eligibility_criteria</td>
<td>multiple</td>
<td>Instance of Criterion</td>
<td></td>
</tr>
<tr>
<td>goal</td>
<td>multiple</td>
<td>Instance of Conditional_G...</td>
<td></td>
</tr>
<tr>
<td>(o) label</td>
<td>required</td>
<td>String</td>
<td></td>
</tr>
<tr>
<td>patient_characterization</td>
<td>multiple</td>
<td>Instance of Diagnostic_Te...</td>
<td></td>
</tr>
<tr>
<td>(o) references</td>
<td>multiple</td>
<td>Instance of Supporting_M...</td>
<td></td>
</tr>
<tr>
<td>(o) subguidelines</td>
<td>multiple</td>
<td>Instance of Management_...</td>
<td></td>
</tr>
<tr>
<td>title</td>
<td>single</td>
<td>String</td>
<td></td>
</tr>
<tr>
<td>version</td>
<td>single</td>
<td>String</td>
<td></td>
</tr>
<tr>
<td>:DOCUMENTATION</td>
<td>multiple</td>
<td>String</td>
<td></td>
</tr>
</tbody>
</table>
The same guideline ontology can structure knowledge bases for lots of conditions!

ATHENA Hypertension

ATHENA Heart Failure

ATHENA Hyperlipidemia

ATHENA Diabetes

ATHENA Renal Disease

ATHENA Opioid Therapy
Learning Health Systems Need Ontology

• To structure what we know about
  – Patients
  – Illnesses
  – Interventions
  – Guidelines for applying interventions
• To make clear what it is that we know
• To help us identify what we don’t know
• To support the encoding of new knowledge for use by computers