Modeling Decision Support for Clinical Guidelines Using the SAGE Guideline Workbench and SNOMED CT

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Introductions

- Who are we?
- Who are you?
  - Training and experience:
    - Clinical understanding
    - Computer science background
  - Interests
    - Guidelines and decision support
    - Interoperation and challenges in deploying standards
Learning Objectives

1. Appreciate the challenges in formulating guidelines into executable algorithms
2. Understand the standardization challenges to creation of interoperable guideline decision support
3. Understand basic procedures for formulation of decision logic and concept inventory
4. Understand the spectrum of vocabulary services necessary for use of SNOMED CT and other NCVHS vocabularies in a decision support environment
5. Describe the function, capabilities and limitations of reference terminologies including SNOMED CT for use in decision support
6. Appreciate the functional requirements and utilities required for a workbench supporting guideline modeling
7. Understand the issues and tasks required for end-to-end modeling of executable guidelines
Overview

- Discussion of guidelines and challenges to decision support development

SAGE guideline modeling process:
- Introduction: Modeling the immunization guideline
- Creating the implementation scenarios and assembling decision logic
- Developing concept inventory: employing standard vocabulary
- Specifying information queries
- SAGE guideline model and workbench
- Encoding immunization guideline
- Validating the development
- Demonstration: SAGE at work
What are Guidelines?

- Guideline(n): a cord or rope to aid passage over a difficult point (Merriam-Webster)
- Systematic statements of evidence-based policy rules or principles to assist clinicians and patients make decisions on healthcare alternatives
- Characteristics
  - May be developed by government agencies at any level, institutions, professional societies, governing boards, or by convening expert panels.
  - May be in narrative, outline, flowchart or tabular forms
  - Need to be formalized to provide computerized clinical decision support at point of care
Why Study Guidelines?

President’s Information Technology Advisory Committee
“Transforming Health Care through Information Technology” (2001)

Findings:
• The U.S. lacks a broadly disseminated and accepted national vision for information technology in health care
• The introduction of integrated decision-support systems that can proactively foster best practices and reduce errors requires enhanced information-technology methods and tools

Recommendations:
• Develop guidelines based on evidences and best practices
• Implement guidelines so that they are usable effectively at the point of care, including embedded decision support that is continually updated as new evidence accumulates
Clinical Decision Support: Comments on a long History

- **1970-80s:** Basic studies in expert systems and reminder technology convinced many of CDSS importance.
- **1990s:**
  - Appearance of practice guidelines as authoritative reference for standard of care.
  - Development of SNOMED and Read V3 as reference terminologies for clinical care systems.
  - Developing importance of **ontologies** in scalable systems design.
Clinical Decision Support: Comments on a long History

• 1970-80s: Basic studies in expert systems and reminder technology convinced many of CDSS importance

• 1990s:
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  - Development of SNOMED and Read V3 as reference terminologies for clinical care systems
  - Developing importance of ontologies in scalable systems design


CDSS = domain ontology + problem solving method
(Partial) Guideline Model Chronology

Adapted from:

Oriented to single rules; ANSI standard; terminology left to “curly braces problem”

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(Partial) Guideline Model

Oriented to single rules; ANSI standard; terminology left to “curly braces problem”

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InterMed consortium; not integrated with CIS; limited deployment

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Stanford system being transferred to and used at VA

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Oriented to advising on prescribing practices in chronic disease management

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Requirements of CDSS

- Automated within clinical workflow
- Provision of guidance for care (not diagnoses)
- Timely delivery at point of decision making
- Computer-based decision support; linked with computer patient data base
- Easily encoded and maintained knowledge bases
Guideline Decision Support
Prerequisites

1) Identifying an opportunity for clinical process improvement
2) Recognizing an authoritative body of recommendations based upon outcomes research (or reputable best practice model)
3) Maintaining a data base of reliable and useful clinical data
4) Having the tools at hand to organize the knowledge into computable form
5) Obtaining support and involvement of the clinical community
6) Assuring use of vendor tools for implementing within clinical record software
SAGE Project Overview

- Collaborative research and development project to develop a standards-based technology to enable encoding and dissemination of guidelines in executable format.
- Infrastructure will employ informatics standards including Protégé open source workbench, HL7 RIM, SNOMED CT and LOINC, and deployment technology to support encoding and dissemination of guidelines across vendor platforms and throughout the spectrum of care.
- Guideline deployment technology will present guideline content to clinicians through active, patient-specific recommendations surfaced through functions of the local clinical information system, and integrated into the care workflow.

SAGE is partially supported under a grant from the U.S. Department of Commerce, National Institute of Standards and Technology, Advanced Technology Program, Cooperative Agreement Number 70NANB1H3049.
If Needed Stabilization?

- Yes
  - Recommend self-management program:
    - Nutrition therapy
    - Physical Activity
    - Education for self-management
    - Foot care
    - Set individualized treatment goals:
      - Glycemic control: HbA1c < 7%
      - Lipid levels: LDL < 130 mg/dl
      - BP control: BP < 130/85 mm Hg
      - ASA unless contraindicated
      - Tobacco cessation if indicated
  - No
    - Treatment goals not met:
      - Modify treatment based on appropriate guideline
      - See Glycemic Control Algorithm
      - Consider referral to diabetes health team or specialists

Are Treatment Goals Met?

- Yes
  - See Ongoing Management Algorithm for maintaining treatment goals and complication prevention

**Initial stabilization for outpatients requiring immediate insulin treatment**
SAGE Infrastructure: Guideline Execution

- Guideline File(s)
- Host Clinical Information Systems
- Guideline Deployment System
  - Standards-based API
  - Common Layer of Terminologies and Information Models
    - Patient Data Model (Virtual Medical Record)
    - Care Workflow Model
    - Medical Ontologies
    - Health Care Organization Model
  - SAGE Guideline Engine
    - SAGE File(s)
Use of Protégé for Guideline Modeling

- Protégé a good rapid prototyping tool
  - For developing guideline ontologies
  - For encoding instances of guidelines
- Protégé an extensible knowledge-engineering platform
  - Plugin architecture allows SAGE-specific extensions
  - API allows decision-support application to access knowledge base
Overview

• Overview of guidelines and challenges to decision support development

SAGE guideline modeling process:
• Identifying the source clinical guideline
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• Validating the development
• Demonstration: SAGE at work
SAGE Guideline Encoding Process

1. Assemble Source Guidelines
2. Envision Clinical Scenarios
3. Formalize Guideline Logic
4. Define Guideline Concepts
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Guideline Installation and Execution
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Source Guideline: CDC Immunizations

- US Center for Disease Control (CDC): Advisory Committee on Immunization Practices (ACIP) issues vaccination schedules (download)

- Birth-death guideline for all vaccinations advised for US healthcare
Encoded Guideline: CDC Immunizations

- 75 complex decision rules
- 172 source clinical concepts
- 1200 criteria in run-time logic
# Pediatric Immunization Sub-guideline Schedule

## Recommended Childhood and Adolescent Immunization Schedule

<table>
<thead>
<tr>
<th>Vaccine</th>
<th>Age</th>
<th>Birth</th>
<th>1 month</th>
<th>2 months</th>
<th>4 months</th>
<th>6 months</th>
<th>12 months</th>
<th>15 months</th>
<th>18 months</th>
<th>24 months</th>
<th>4-6 years</th>
<th>11-12 years</th>
<th>13-14 years</th>
<th>15 years</th>
<th>16-18 years</th>
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<tbody>
<tr>
<td>Hepatitis B&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
<td>HepB</td>
<td>HepB</td>
<td>HepB&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>HepB Series</td>
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<td>Diphtheria, Tetanus, Pertussis&lt;sup&gt;2&lt;/sup&gt;</td>
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<td>DTaP</td>
<td>DTaP</td>
<td>DTaP</td>
<td>DTaP</td>
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<td>DTaP</td>
<td>Tdap</td>
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<td>Haemophilus influenzae type b&lt;sup&gt;3&lt;/sup&gt;</td>
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<td>Hib</td>
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<td>Inactivated Poliovirus</td>
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<td></td>
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<td>MMR</td>
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<td></td>
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<td>Varicella</td>
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<td>Influenza (Yearly)</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>HepA Series</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

*Vaccines within broken line are for selected populations.*
# Recommended Adult Immunization Schedule, by Vaccine and Age Group

**UNITED STATES, OCTOBER 2005—SEPTEMBER 2006**

<table>
<thead>
<tr>
<th>Vaccine</th>
<th>19–49 years</th>
<th>50–64 years</th>
<th>≥ 65 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tetanus, diphtheria (Td)(^1)*</td>
<td>1-dose booster every 10 yrs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measles, mumps, rubella (MMR)(^2)*</td>
<td>1 or 2 doses</td>
<td>1 dose</td>
<td></td>
</tr>
<tr>
<td>Varicella(^3)*</td>
<td>2 doses (0, 4–8 wks)</td>
<td>2 doses (0, 4–8 wks)</td>
<td></td>
</tr>
<tr>
<td>Influenza(^4)*</td>
<td>1 dose annually</td>
<td>1 dose annually</td>
<td></td>
</tr>
<tr>
<td>Pneumococcal (polysaccharide)(^5,6)</td>
<td>1–2 doses</td>
<td></td>
<td>1 dose</td>
</tr>
<tr>
<td>Hepatitis A(^7)*</td>
<td>2 doses (0, 6–12 mos, or 0, 6–18 mos)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hepatitis B(^8)*</td>
<td></td>
<td>3 doses (0, 1–2, 4–6 mos)</td>
<td></td>
</tr>
<tr>
<td>Meningococcal(^9)</td>
<td></td>
<td></td>
<td>1 or more doses</td>
</tr>
</tbody>
</table>

*Note: These recommendations should be read with the entire schedule.*
Guidelines are Dynamic

- Recent provisional recommendations of the Advisory Committee on Immunization Practice (ACIP)
  - Varicella: 2 dose recommendation for all ages (August 2006)
  - HPV: 3 dose series for females ages 9-26 (August 2006)
  - Tdap:
    - use in pregnant women (August 2006)
    - Use in adult population (March 2006)
Guideline Focus: CDC Adult Pneumococcal Guideline

**Pneumococcal Polysaccharide Vaccine Recommendations**
- Adults ≥65 years of age
- Persons ≥2 years with
  - chronic illness
  - anatomic or functional asplenia
  - immunocompromised (disease, chemotherapy, steroids)
  - HIV infection
  - environments or settings with increased risk
  - cochlear implant

**Pneumococcal Polysaccharide Vaccine Revaccination**
- Routine revaccination of immunocompetent persons is not recommended
- Revaccination recommended for persons age ≥2 years at highest risk of serious pneumococcal infection
- Single revaccination dose ≥5 years after first dose
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- Overview of guidelines and challenges to decision support development

SAGE guideline modeling process: Introduction
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7. Encode Guideline Knowledgebase
In automating complex guidelines … the most difficult (obstacle was) related to workflow integration.”

Maviglia et al. *J Am Med Inform Assoc.* 2003; 10: 154-165
Creating Guideline Scenarios

- Workflow process that approximates the typical clinical practice
- With an efficient work model that does not control or distort work activities
- Target interactions with the most appropriate individual
- Multi-faceted interventions
- Locally – some need for modifications to match local workflow and CIS capabilities
Creating Guideline Scenarios

- Focus upon a clinical opportunity
- Have a specified trigger (initiating information event)
- Construct understanding the CDSS and CIS capabilities; digital clinical data available
- Include plans for decision support, recording of data required for good care, and monitoring of CDSS function
Primary Care Visit Scenario

- **Check-in process**
  - Patient arrives at primary care office requesting care.
  - The patient is checked in to clinic
- **Nurse interaction**
  - Patient is called for preparation by the nurse.
  - The nurse logs onto the clinic information system and selects the patient record.
  - Vitals are taken and entered into the CIS
- **Physician visit**
  - Physician assesses patient and makes recommendations/orders
- **Variable check-out process**
Primary Care Visit Scenario

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CDSS intervention
Primary Care Visit Scenario

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• Physician visit
  – Physician assesses patient and makes recommendations/orders
• Variable check-out process

CDSS intervention
Primary Care Visit Scenario

- CDSS is triggered
- Review of patient’s record for indication/contraindication:
  - vaccination history
  - problem list
  - procedure history
- Physician notified of due, but contraindicated vaccines
- Nurse informed of eligibility and appropriate vaccination information sheets are printed for the patient or parent to read.
- The nurse is prompted to obtain and document consent and verify that the patient does not have an inter-current illness that would prevent vaccination today.
Primary Care Visit Scenario

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CDSS intervention
Primary Care Visit Scenario

• Clinical record assessed for any known deferral reasons and those vaccines are removed from the list of those to be administered.
• Automated care orders are placed in the system for the vaccines which the patient is to receive.
• The nurse charts against these care orders as she administers the vaccines to the patient, updating the master record.
Primary Care Visit Scenario

- Clinical record assessed for any known deferral reasons and those vaccines are removed from the list of those to be administered.
- Automated care orders are placed in the system for the vaccines which the patient is to receive.
- The nurse charts against these care orders as she administers the vaccines to the patient, updating the master record.
Population Management Scenario

• Every Sunday at midnight, a batch program starts within the clinical information system for a rural health clinic.

• The program checks each patient record within the practice and reviews the vaccination history and all record data pertinent to indications and contraindications for vaccinations.

• It identifies all patients who have come due for vaccines and issues a report for the clinic manager who coordinates the scheduling for patients who need immunization.
Neonatal Birth Scenario (Admission to Nursery)

- A baby is admitted to the nursery in a local hospital following birth in the L&D suite. The admission event is tracked by SAGE which checks for eligibility against the child’s and mother’s clinical records.

- SAGE recommends orders for Hepatitis B vaccine and Hepatitis immune globulin as appropriate.

- Orders for follow-up serologic testing at nine months of age are issued when exposure status is positive or uncertain.

- When mother’s serologic status for Hep B is unknown, SAGE issues orders for maternal testing and tracks results until obtained.
Alternative Scenarios?

- All patients seeking service in the emergency department or urgent care facility have reminders issued for vaccines
- All patients being discharged from hospital have vaccine requirements reviewed and alerts issued
- The home health visitor has automated alerts generated for the list of scheduled patients who are due for vaccination
- A long term care facility is issued automated orders verifying eligibility for overdue vaccinations
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Guideline Installation and Execution
Use Case: CDC Adult Pneumococcal Guideline

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Decision Logic Inventory

Recommendation set: Adult Pneumococcal polysaccharide vaccine (PPV23)

Contraindication := Anaphylaxis reaction to pneumococcal vaccine

Deferral := Moderate or severe current illness
                                      two weeks prior to chemotherapy or radiation therapy

Indication :=
   Immunosuppressed (defined):
   - HIV infection
   - Leukemia
   - Lymphoma (includes Hodgkins)
   - Multiple myeloma
   - Generalized malignancies
   - Congenital immunosuppression
   - Immunodeficiency caused by chemotherapy
   - Solid organ transplant
   - Bone marrow transplant
   - Chemotherapy with alkylating agents within last three months
   - Antimetabolite therapy
   - Long term steroid therapy

Functional and Anatomic Asplenia (defined):
   - Splenectomy
   - Congenital Asplenia
   - Asplenia syndrome
   - Functional asplenia
   - Hypoasplenia

Sickle cell disease
   Chronic cardiac disease or
   Chronic pulmonary disease excluding asthma or
   Diabetes mellitus or
   CSF leak or
   Hemodialysis patient or
   Health care worker or
   Emergency response personnel or
   Terminal complement component deficiencies or
   Chronic liver disease or
   Chronic alcoholism
   Cochlear implant
   Native American
   Pregnancy
   Chronic transfusion patient (more than 3 transfusions last 6 months)
   Nursing home resident
Recommendation set: One subset of guideline recommendations that can be implemented in a single work plan.

**Recommendation set**: Adult Pneumococcal polysaccharide vaccine (PPV23)

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**Deferral**: Moderate to severe current illness
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Decision Logic Inventory

Requires review and integration of all decision elements:
• contraindications
• deferrals
• indications

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• indications

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- **Deferral:**
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  - Two weeks prior to chemotherapy or radiation therapy
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  - Immunocompromised (defined):
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    - Lymphoma (includes Hodgkins)
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    - Congenital immunosuppression
    - Immunodeficiency caused by chemotherapy
    - Solid organ transplant
    - Bone marrow transplant
    - Chemotherapy with alkylating agents within last three months
    - Antimetabolite therapy
    - Long-term steroid therapy
  - Functional and Anatomic Asplenia (defined):
    - Splenectomy
    - Congenital Asplenia
    - Asplenia syndrome
    - Functional asplenia
    - Hyposplenism
  - Sickle cell disease
  - Chronic cardiac disease or
  - Chronic pulmonary disease excluding asthma or
  - Diabetes mellitus or
  - CSF leak or
  - Hemodialysis patient or
  - Health care worker or
  - Emergency response personnel or
  - Terminal complement component deficiencies or
  - Chronic liver disease or
  - Chronic alcoholism
  - Cochlear implants
  - Native American
  - Pregnancy
  - Chronic transfusion patient (more than 3 transfusions last 6 months)
  - Nursing home resident
Decision Logic Inventory: Which Vaccine to Administer?

Rule 1: Adult First Dose PPV23

IF NO CONTRAINDICATION
    AND
    NO REASON FOR DEFERRAL
    AND
    NUMBER OF PPV23 VACCINE DOSES = 0
    AND
    INDICATION FOR PNEUMOCOCCAL VACCINE OR (AGE>=65 YEARS)
THEN
    ADVISE ADMINISTRATION OF PPV23 VACCINE

Rule 2: Adult Second dose PPV23

IF NO CONTRAINDICATION
    AND
    NO REASON FOR DEFERRAL
    AND
    NUMBER OF PPV23 VACCINE DOSES=1
    AND
    (SUBGROUP INDICATIONS FOR REVACCINATION) OR
    ((AGE > 65 YEARS) AND (PPV23 VACCINE DOSE GIVEN < AGE 65 YEARS))
    AND
    PPV23 ADMINISTERED >=5YEARS PREVIOUSLY
THEN
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AND
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THEN ADVISE ADMINISTRATION OF PPV23 VACCINE
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Must specify all clinical details required for complete deployment.
Overview

- Overview of guidelines and challenges to decision support development

SAGE guideline modeling process:
- Identifying the source clinical guideline
- Creating the implementation scenarios and assembling decision logic
- Developing concept inventory: employing standard vocabulary
- Specifying information queries
- SAGE guideline model and workbench
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- Validating the development
- Demonstration: SAGE at work
SAGE Guideline Encoding Process

1. Assemble Source Guidelines
2. Envision Clinical Scenarios
3. Formalize Guideline Logic
4. Define Guideline Concepts
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Guideline Installation and Execution
SAGE Guideline Encoding Process

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Guideline Installation and Execution
Reviewing Concept Inventory: Binding to Standard Vocabulary

- Concepts present in the guideline may require clinical discussion and definition.
- Once clarified and matched into information model requirements, meaning must be reviewed against the appropriate vocabulary domain (SNOMED CT, LOINC) to assure that the meaning in the guideline corresponds to the meaning to be retrieved from the patient record.
Clarifying Concept Definition...

- What is a chronic illness?
- Functional or anatomic asplenia?
- Who is an immunocompromised person?

Pneumococcal Polysaccharide Vaccine Recommendations

- Adults ≥65 years of age
- Persons ≥2 years with
  - chronic illness
  - anatomic or functional asplenia
  - immunocompromised (disease, chemotherapy, steroids)
  - HIV infection
  - environments or settings with increased risk
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SNOMED CT®

- Under development by the College of American Pathologists since the 1960’s
- Provides a disambiguated, polyhierarchically represented representation of over 350,000 medical concepts, with approximately 1 million descriptions
- Under licensing agreement with the NLM
- Crossmaps to other commonly-used terminologies are built in
- Presently the most complete formal medical ontology in existence
Why do we need SNOMED CT?

- **Synonyms**
  - By assigning a unique numeric code to each medical concept, SNOMED CT formalizes clinical terminology.

- **Subsumption**
  - By representing the complete set of relationships among medical concepts, SNOMED CT automates classification logic.

- **Ambiguity**
  - By assigning different codes to homonyms, SNOMED CT disambiguates medical language.
The Inheritance Hierarchy

Concepts are arranged in a tree hierarchy

- Medication
  - Antibiotic
    - Penicillin
      - Ampicillin
    - Quinolone
      - Beta-blocker
        - Atenolol
        - Betaxolol
    - Anti-HTN
      - Metoprolol
  - Diuretic
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The Inheritance Hierarchy

Concepts are arranged in a tree hierarchy

Medication

Antibiotic

Penicillin

Ampicillin

Methicillin

Quinolone

Anti-HTN

Beta-blocker

Atenolol

Betaxolol

Diuretic

Metoprolol

Antibiotic subsumes Penicillin and Methicillin
A concept may have more than one parent in the hierarchy.
A concept may have more than one parent in the hierarchy.
A concept may have more than one parent in the hierarchy.
Pre- and Post-Coordination

Suprarenal Artery Embolus
297143008

or

Is_a  Occlusion of Artery 2929001
   Associated Morphology 116676008
      Embolus 55584005
   Finding Site 363698007
      Suprarenal Artery 89500000
Pre- and Post-Coordination

Suprarenal Artery Embolus 297143008

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Pre-Coordinated
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**Pre-Coordinated**
Pre- and Post-Coordination

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Vocabulary Formalization: Overview

- Once a concept from the guideline is clear and has an understandable meaning, it is compared against SNOMED-CT or other vocabulary concepts in the assigned domain:
  - Is it pre-coordinated?
  - Is the SNOMED definition and all children consistent with the scope of guideline meaning?
  - Can it be defined within standard vocabularies or is it outside the scope of standards and require an extension?
Example...

Pneumococcal Polysaccharide Vaccine Recommendations

- Adults ≥65 years of age
- Persons ≥2 years with
  - chronic illness
  - anatomic or functional asplenia
- Immunocompromised (disease, chemotherapy, steroids)
- HIV infection
- Environments or settings with increased risk
  - cochlear implant
“Functional or anatomic asplenia”

- **Clinical Definition**
  - Congenital asplenia
  - Congenital hypoplasia of spleen
  - Splenectomy
  - Splenic atrophy
  - Sickle cell disease

- **SNOMED CT Concept**
  - 93030006
  - 93292008
  - 234319005 (Procedure)
  - 82893001
  - 127040003 (Hemoglobin S disease)
"Functional or anatomic asplenia"

- Clinical Definition
  - Congenital asplenia
  - Congenital hypoplasia of spleen
  - Splenectomy
  - Splenic atrophy
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Guideline Installation and Execution
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Why do we need to specify Information Queries?

- The CDSS must obtain patient data from the CIS to perform logic
- Every CIS represents patient data differently
  - Physical model
    - Object-oriented vs. Relational
  - Logical Model
    - Variation in patient data components

Example
Possible Documentations of a Patient’s “Diabetes Mellitus”

- Entry on Problem List
  - Diabetes Mellitus type II

- Observation
  - Lab Value of Fasting Glucose > 125 mg/dL or
  - Lab value for two-hour 75-g oral glucose tolerance test > 200 mg/dL

- Entry in Diagnoses & Procedures list
  - Diabetes Mellitus type II
Implications of Representation Variability

• Guideline logic needs to consider
  – Looking for different types of information
    • Observations, Problem list, procedures, etc.
    • May need to combine multiple queries to get one logical conclusion

• Need a common representation of:
  – The places to look
    • CIS information model
  – The data we’ll find
    • Standard terminology
A Common Representation of Queries

- Must be able to interact correctly with any vendor information model
- Since we cannot tell CIS vendors how to structure their systems, the SAGE approach to interoperability is to use a standard information model and then have each vendor build their own translation from the standard to their system
The vMR..

- Virtual Medical Record
  - Standardized way of representing the CIS information model
  - Created based on the Health Level 7 v3 Reference Information Model (HL7 RIM)
    - Clinical Decision Support Technical Committee
    - Clinical Statements Model
  - Defines an idealized information model
    - “things that can be recorded about patients”
      - Problems, Observations, Medications, etc.
  - Our standard terminologies populate the slots
- An “interlingua” for representing Clinical data
RIM Core Classes

Entity
- Organization
- Living Subject
- Material
- Place
- Health Chart

Role
- Patient
- Employee
- Healthcare provider
- Practitioner
- Practitioner assignment
- Specimen

Participation

Act
- Transportation
- Supply
- Consent
- Referral
- Procedure
- Observation
- Medication
- Medication
- Financial act

Relationship Link
- 0..* 0..*
- 1 1

Act Relationship
- 0..* 0..*
- 1 1
RIM Core Classes

- **Entity**: Organization, Living Subject, Material, Place, Health Chart
- **Role**: Patient, Employee, Healthcare provider, Practitioner, Practitioner assignment, Specimen
- **Relationship Link**: 0..* 0..* 1 1 0..* 0..* 1 1
- **Participation**: 0..* 0..* 1 1
- **Act**: 0..* 0..* 1 1
- **Act Relationship**: Transportation, Supply, Consent, Referral, Procedure, Observation, Medication, Financial act
SAGE Guideline Deployment System Execution Architecture

**SAGE Execution Engine**

- Event Listener
  - Event Notifications
  - VMR Service calls
  - Action Service calls

**Terminology Server**

**Other Servers**

**VMR Services Action Interface**

- Terminology Functions
  - Standards-based I/F based on web services

**Clinical Information System**

- CIS-specific implementation of services

**SAGE Guideline Deployment System Execution Architecture**

- ENCODED GUIDELINE
  - Terminology Functions
  - VMR Service calls
  - Action Service calls
  - Event Notifications
In the guideline model, patient data concepts are represented using VMR classes.

Queries for patient data are represented using standard VMR-based methods.

Patient data queries are processed via VMR Service web service.

Generic methods are “mapped” to CIS-specific methods.

Data objects returned to SAGE Engine are built from HL7 data types.

VMR-based query for lab data:
Example: getObservations [Creat]

Observation object(s) returned:
Local CIS method for: returning Creat lab values

Lab Results
VMR Services Interface

- In the guideline model, patient data concepts are represented using VMR classes
- Queries for patient data are represented using standard VMR-based methods
- Patient data queries are processed via VMR Service web service
- Generic methods are “mapped” to CIS-specific methods
- Data objects returned to SAGE Engine are built from HL7 data types

Example: `getObservations [Creat]`
Virtual Medical Record Objects (SAGE Idealized Information Model)

- Substance administration
- Referral
- Procedure
- Problem
- Order (non-medication)
- Medication order

- Observation
- Goal
- Encounter
- Appointment
- Adverse reaction
- Agent
- Alert
Virtual Medical Record Objects (SAGE Idealized Information Model)

- Substance
- Observation
- Procedure
- Problem
- Order (non-medications)
- Medication order
- Appointment
- Adverse reaction
- Agent
- Alert

Observation where code is 'HEPATITIS B VIRUS SURFACE AG:ACNC:PT:SER:ORD: [LOINC]' value is 'Positive (qualifier value) [SNOMED CT]'
Interaction of vMR and Vocabulary

- "Family history of colon cancer"
  - Observation: code = 275937001|"family history of colon cancer"
  - Observation: code = 363406005|"colon cancer", subject = 303071001|"family member"

- "Elevated blood sugar"
  - Observation: code = 166892002|"random blood sugar raised"
  - Observation: code = 2339-0|"Blood glucose", value = 250mg/dl
Interaction of vMR and Vocabulary

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Overlap of terminology and information model semantics
1. Is data stored in a “family history” table?
2. Is this on the problem list?
Interaction of vMR and Vocabulary

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- "Elevated blood sugar"
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  - Observation: code = 2339-0|"Blood glucose", value = 250mg/dl

Data and information co-exist in the CIS
1. Already interpreted information?
2. Raw data
Pragmatics of Clinician Use

• Is encounter data reliably recorded? When is it available?
• Does nursing staff record vital signs and I&O real-time?
• Who places orders in the system? When are they recorded?
• When do lab results cross the interface and appear in the CIS?
• Do the physicians use the problem list?
• Are procedures recorded as they are billed?
Questions?

- BREAK

- Part 2:
  - SAGE Guideline model and Protégé Workbench
  - Encoding the immunization guideline
  - Validation and localization of the guideline
  - DEMONSTRATION: Execution of the encoded guideline within clinical information system
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Model-Based Approach to Encoding Guidelines

- **Model**: a simplified abstraction of a system (guideline), aimed at understanding and/or explaining aspects of interest
- **Templates** for specifying computer-interpretable guideline knowledge
- **Guideline**: “…systematically developed statements to assist practitioner and patient decisions about appropriate health care for specific clinical circumstances” (Field, 1990)
SAGE Guideline Model and Modeling Environment

- Use Protégé as guideline modeling and encoding environment
- 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
Structure of a SAGE Guideline
A guideline contains sets of recommendations and other properties.
Structure of a SAGE Guideline

A guideline contains sets of recommendations and other properties.

A recommendation set contains contexts, decisions, and actions that are linked by transitions.
A Guideline Recommendation: Basic Components
A Guideline Recommendation: Basic Components

**Context Nodes** organize and specify the relationship to workflow.
- What triggers the session
- Who is involved
- Where the session occurs
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- What triggers the session
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Decision Nodes provide support for making choices:
- Specification of alternatives
- Logic used to evaluate choices

A Guideline Recommendation: Basic Components
A Guideline Recommendation: Basic Components

**Context Nodes** organize and specify the relationship to workflow.
- What triggers the session
- Who is involved
- Where the session occurs

**Decision Nodes** provide support for making choices:
- Specification of alternatives
- Logic used to evaluate choices

**Action Nodes** define activity to be accomplished by CIS:
- User interaction, query, messaging
- Order sets
- Appointments and referrals
- Goal setting
- Documentation and recording
A Decision Node contains reasons for choosing each alternative.
A Decision Node contains reasons for choosing each alternative.
A Decision Node contains reasons for choosing each alternative.

Rule-in and rule-out criteria determines whether an alternative is recommended.
Features of SAGE Protégé Workbench

- Navigation and search: KWIZ tab
- Generation of XML/HTML: kb2doc tab
- Constraint checking: FacetConstraint tab & PALConstraint tab
- Terminology service: Apelon DTS plugin
- Case-based testing: SAGE tab
• Alternative navigation
• Enhanced Search
• Re-use of instances from other projects
XML/HTML Guideline View

- Uses a separate Protégé knowledge base to specify how XML should be generated from instances
- Uses XSLT to transform XML to HTML
Constraint Checking: PAL and Facet Constraint Tabs

- PALConstraint tab: Learning curve
- FacetConstraint tab: Problems with performance
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Guideline Installation and Execution
Demo of Encoding Exercise: Adult Pneumococcal Vaccine
Guideline Logic

Rule 1: Adult First Dose PPV23

IF NO CONTRAINDICATION
AND
NO REASON FOR DEFERRAL
AND
NUMBER OF PPV23 VACCINE DOSES = 0
AND
INDICATION FOR PNEUMOCOCCAL VACCINE OR (AGE ≥ 65 YEARS)
THEN
ADVISE ADMINISTRATION OF PPV23 VACCINE

Rule 2: Adult Second dose PPV23

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AND
((SUBGROUP INDICATIONS FOR REVACCINATION))
OR
((AGE > 65 YEARS) AND (PPV23 VACCINE DOSE GIVEN < AGE 65 YEARS))
AND
PPV23 ADMINISTERED ≥ 5 YEARS PREVIOUSLY
THEN
ADVISE ADMINISTRATION OF PPV23 VACCINE

Recommendation set: Adult Pneumococcal polysaccharide vaccine (PPV)

Contraindication := Anaphylactic reaction to pneumococcal vaccine

Deferral := Moderate of severe current illness

Indication :=
- Chronic cardiac disease or
- Chronic pulmonary disease excluding asthma or
- Diabetes mellitus or
- CSF leak or
- Hemodialysis patient or
- Healthcare worker or
- Emergency response personnel or
- Terminal complement component deficiencies or
- Chronic liver disease or
- Chronic alcoholism
- Cochlear implants
- Native American
- American Indian
- Pregnancy
- HIV+
- Congenital hypoplasia of spleen
- Splenic atrophy
- Splenectomy
- Chronic renal failure
- Institutionalized
- Sickle cell disease
- Nephrotic syndrome
- Solid organ transplant
- Long term steroid therapy (12 glucocorticoid doses last six mont
- Antimetabolite therapy
- Chronic transfusion patient (more than 3 transfusions last 6 mo
- Immunodeficiency due to chemotherapy
- Functional asplenia
- Multiple myelomas
- Generalized malignancy
- Bone marrow transplant recipient
- Congenital immunodeficiency
- Chemotherapy with alkylating agents within last 3 months
- Nursing home resident
Encoding example
PPV23 possibly due (Adult) (instance of Alternative_Choice, internal name is ...)

Alternative
- PPV23 possibly due (Adult)

Recommendation Threshold
- 1

Strict Rule Out
- # of PPV23 doses >= 2
- PPV23 first dose indicated (adult)
- PPV23 second dose (adult)

Strict Rule In

PPV23 first dose indicated (adult)

(instance of N_ary_Criterion, internal name is ...)

Label
- PPV23 first dose indicated (adult)

Criteria
- Number of PPV23 vaccine doses = 0
- Age >= 65 OR PPV23 adult indications

Boolean Connective
- AND
Chronic heart disease
invoke Apelon DTS plugin
Apelon DTS Plugin

Search

Concept details
Overview

- Overview of guidelines and challenges to decision support development

SAGE guideline modeling process:
- Identifying the source clinical guideline
- Creating the implementation scenarios and assembling decision logic
- Developing concept inventory: employing standard vocabulary
- Specifying information queries
- SAGE guideline model and workbench
- Encoding immunization guideline
- Validating the development
- Demonstration: SAGE at work
SAGE Guideline Encoding Process

1. Assemble Source Guidelines
2. Envision Clinical Scenarios
3. Formalize Guideline Logic
4. Define Guideline Concepts
5. Formalize Vocabulary Inventory
6. Specify Information Queries
7. Encode Guideline Knowledgebase

Guideline Installation and Execution
SAGE Guideline Encoding Process

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Guideline Installation and Execution
• Guideline workflow logic is often more complicated than simple rules
• With increased scenario complexity, the probability of errors rises geometrically
• CDSS environment should therefore allow for workbench testing
• Internal consistency checking of bindings and data constraints should be integrated within the CDSS workbench
Guideline Review

Medical Staff Review Guideline
Guideline Review

Protégé Workbench

Document-Oriented View
Guideline Review

Protégé Workbench

Document-Oriented View
Guideline Review

Protégé Workbench

Document-Oriented View

Immunizations

SAGE Cycle 5 Immunization guidelines. All patients eligible for vaccination regardless of age and clinical condition.

- Meta data:
  - Guideline Metadata
    - id: ImmunizationCycle5
    - title: Immunization course guidelines
    - version: ImmunizationCycle5
    - category: Prevention
    - date: 2005/11/1
    - developers: Bob Mccrae, Susan Ten Kerschbroek, Jim Campbell
  - recommendation set:
    - Neonatal Hepatitis Immunization Guideline
      - Disease Care Immunizations
      - Adult Immunizations
      - Overview
      - Prevent epidemic hepatitis
      - Vaccine efficacy
      - Immunization Schedule
      - Population management strategies
      - Text only

Recommendation Set (Activity Graph): Neonatal Hepatitis Immunization Guideline

- Determines whether Hepatitis B vaccine is due, checks upon admission and places orders when appropriate.
- Orders follow-up testing at one month of age if the infant is at risk.
- Determines whether Hepatitis B vaccine is due to the patient order.
- Checks maternal record for information of Hepatitis B status. If there is no record, orders are placed for maternal testing and base done record is set for 15 days until the patient is discharged or the baby is more than 24 hours old.
Guideline Review

Protégé Workbench

Document-Oriented View

Immunizations

SAGE Cycle 3 Immunization guideline: All patients eligible for vaccination regardless of age and clinical condition.

- patient_data
  - Guideline Metadata
    - title: Immunization cycle 3
    - version: 3.0
    - date: 2009-11-11
    - authors: Bob McClure, Susan Thorpe, Shah Campbell
    - recommendation set
      - Neonatal Hepatitis Immunization Guideline
        - Induction Immunizations
          - Hepatitis B Vaccine
          - Hepatitis B Immune Globulin
          - Titration Immunizations
            - Hepatitis B Vaccine
            - Hepatitis B Immune Globulin
            - Hepatitis A Vaccine

Recommendation Set (Activity Graph): Neonatal Hepatitis Immunization Guideline

- newborn ( Neonatal Hepatitis Immunization Scenario )
  - steps:
    1. Determine whether Hepatitis B vaccine is due, check verbal and place order when appropriate.
    2. Order follow-up testing after receipt of age and then send order.
    3. Ensure whether Hepatitis B immune globulin is in the patient order.
    4. Order maternal record for information of Hepatitis B status.

If there is no record for Hepatitis B, order is placed for maternal testing and have done result set for 15 hours and the result to the lab in no more than 24 hours.
Guideline Localization

- Local “edits” to guideline content might include:
  - Minor changes (thresholds, formulary, etc.)
Guideline Localization

- Major changes (workflow, goals, decisions)
Guideline Localization

- Major changes (workflow, goals, decisions)
Guideline Localization

- Major changes (workflow, goals, decisions)

Generic Guideline

Local Care Workflow
Guideline Localization

- Major changes (workflow, goals, decisions)

**Generic Guideline**

**Local Care Workflow**

Do A, then B, then C
Guideline Localization

- Major changes (workflow, goals, decisions)

Generic Guideline  Local Care Workflow

Do A, then B, then C
Guideline Localization

- Major changes (workflow, goals, decisions)

**Generic Guideline**

A → B → C

**Local Care Workflow**

A → B → C

Do A, then B, then C
Guideline Localization

- Major changes (workflow, goals, decisions)

Generic Guideline

A → B → C

Do A, then B, then C

Local Care Workflow

A → B
A → C

Do A, then B and C in parallel
Guideline Localization

- Major change -- decisions
Guideline Localization

- Major change -- decisions
Guideline Localization

- Major change -- decisions

POSITION STATEMENT

Standards of Medical Care in Diabetes-2006

American Diabetes Association

Diabetes is a chronic illness that requires continuing medical care and self-management support. It is a complex disease that affects the body's ability to produce or effectively use insulin, a hormone essential to converting food into energy.

Treatment recommendations and goals

In individuals with overt CVD
- All patients should be treated with a statin to achieve an LDL reduction of 30–40%. (A)
- A lower LDL cholesterol goal of <70 mg/dl (1.8 mmol/l), using a high dose of a statin, is an option. (B)
Guideline Localization

• Major change -- decisions

**Position Statement**

**Standards of Medical Care in Diabetes—2006**

*American Diabetes Association*

**Diabetes is a chronic illness that requires continuing medical care and selfmanagement.**

**Treatment recommendations and goals**

In individuals with overt CVD

• All patients should be treated with a statin to achieve an LDL reduction of 30–40%. (A)

• A lower LDL cholesterol goal of <70 mg/dl (1.8 mmol/l), using a high dose of a statin, is an option. (B)
Guideline Localization

- Major change -- decisions
Guideline Localization

Validate using SAGE Tab
Guideline Localization

Validate using SAGE Tab
Guideline Localization

Validate using SAGE Tab

Log Tab
Guideline Localization

Edit Guideline for Local Conditions

Validate using SAGE Tab

Log Tab
Guideline Localization

Edit Guideline for Local Conditions

Validate using SAGE Tab

Log Tab
Guideline Localization

Validate using SAGE Tab
Guideline Localization

Validate using SAGE Tab
Guideline Localization

Validate using SAGE Tab

Result Tab
Guideline Localization

Validate using SAGE Tab
Guideline Localization

Edit Guideline for Local Conditions

Validate using SAGE Tab

Result Tab
Localization and Binding to Local CIS

- Interoperable model (such as SAGE) assumes compliance with all information and vocabulary standards
- Implementing this model in a system with parochial terminology requires:
  - Review of scenario assumptions for local applicability
  - Exhaustive mapping to local data tables (code sets must be supported)
Mapping Terminologies
Mapping Terminologies

Standards-based coded content in SAGE Guideline
Mapping Terminologies

Standards-based coded content in SAGE Guideline
Mapping Terminologies

Standards-based coded content in SAGE Guideline **Must be** Mapped To
Mapping Terminologies

Standards-based coded content in SAGE Guideline

Must be Mapped To
Mapping Terminologies

Standards-based coded content in SAGE Guideline → Must be Mapped To → Codes and terminologies used in host CIS
Mapping Terminologies

Standards-based coded content in SAGE Guideline

Diabetes Mellitus:
SNOMED-CT 73211009

Must be Mapped To

Codes and terminologies used in host CIS
Mapping Terminologies

Standards-based coded content in SAGE Guideline

Must be Mapped To

Codes and terminologies used in host CIS

Diabetes Mellitus:
SNOMED-CT 73211009
Mapping Terminologies

Standards-based coded content in SAGE Guideline

Diabetes Mellitus: SNOMED-CT 73211009

Must be Mapped To

In the local CIS:
Problem Master Table
Diabetes Mellitus
Sequence # 2566

Codes and terminologies used in host CIS
Mapping Terminologies

Standards-based coded content in SAGE Guideline

Must be Mapped To

Diabetes Mellitus: SNOMED-CT 73211009

Codes and terminologies used in host CIS

In the local CIS:
Problem Master Table
Diabetes Mellitus
Sequence # 2566
Mapping Terminologies

Standards-based coded content in SAGE Guideline

\[ \text{Diabetes Mellitus: SNOMED-CT 73211009} \]

Must be Mapped To

Codes and terminologies used in host CIS

In the local CIS:

Problem Master Table

Diabetes Mellitus

Sequence # 2566
Mapping Terminologies

Standards-based coded content in SAGE Guideline

Diabetes Mellitus: SNOMED-CT 73211009

Must be Mapped To

Diabetes Mellitus: SNOMED-CT 73211009

In the local CIS:
Problem Master Table
Diabetes Mellitus Sequence # 2566

Codes and terminologies used in host CIS
### Mapping Terminologies

<table>
<thead>
<tr>
<th>VMR Context</th>
<th>From concept</th>
<th>From concept label</th>
<th>Mayo label</th>
<th>Mayo lab code</th>
<th>Mayo Concept</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem</td>
<td>SNO: 73211009</td>
<td>Diabetes mellitus</td>
<td>DM</td>
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<td>2202566</td>
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<tr>
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<td>SNO: 46635009</td>
<td>Diabetes mellitus type 1</td>
<td>DM type 1</td>
<td></td>
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<td>Problem</td>
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<td>Diabetes mellitus type 2</td>
<td>DM type 2</td>
<td></td>
<td>2202567</td>
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<td>Rubella Virus Ab</td>
<td>Rubella Abs, IgG Only, S</td>
<td>8172-ROCLIS</td>
<td>6109703</td>
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<tr>
<td>Observation</td>
<td>LOINC: 5195-3</td>
<td>Hepatitis B Virus Surface Ag</td>
<td>Hepatitis Bs Ag (HBsAg), S</td>
<td>9013-ROCLIS</td>
<td>6102663</td>
</tr>
</tbody>
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**VMR Context**

- **From concept**
- **From concept label**
- **Mayo label**
- **Mayo lab code**
- **Mayo Concept**
Validating Run-Time Environment

- Data bases within clinical systems in-use frequently have variable content and may reflect different patterns of usage between sites.
- Demonstration cases are valuable for testing but execution against live (parallel) data often exposes:
  - Need for different pragmatics or expanded decision logic.
  - Failure of model to handle missing or incomplete data.
Validating Run-Time Environment

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For example:
1) Adult patients in US often transfer physicians
2) Immunization history is frequently not recorded in adults
3) Should model make simplifying assumptions regarding primary immunization for Diphtheria / tetanus?
Quality Assurance Safety Monitoring

- Guideline interventions should generally be tracked and recorded on a patient-by-patient basis
- Consider that one or more implementation scenarios should always address monitoring of success and safety events
- Modeling team should review for safety sentinel events, these should be considered as part of implementation plan
Examples of Compliance and Safety Monitoring Scenarios

- Report of non-compliance events issued with summary statistics by site and provider
- Babies leaving hospital without record of Hepatitis B vaccination
- Hospitalization of elderly for pneumonia with no history of pneumococcal or influenza vaccinations and clinic visit within past year
- Elderly discharged from hospital in flu season without vaccination
Overview

• Overview of guidelines and challenges to decision support development

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SAGE Guideline Deployment System Execution Architecture

- **SAGE Execution Engine**
  - Event Listener
  - VMR Service calls
  - Action Service calls
  - Terminology Functions
  - Other Servers
  - Terminology Server

- **VMR Services Action Interface**
  - Binding

- **Clinical Information System**
  - Standards-based I/F based on web services
  - CIS-specific implementation of services
Immunizations Guideline
Primary Care Visit Scenario

- Patient checks into clinic
- Nurse accesses the patient record, triggering CDSS (SAGE)
  - Event sent from web page
- CIS queries problem list, order profile, procedure history and vaccination history to evaluate vaccinations due or due but contraindicated
- In Carecast, Inbox messages sent:
  - ‘Vaccines due or due but contraindicated’
  - Inquire about illness and obtain immunization consent
  - Generate vaccine information sheets (VIS)
- In Carecast, clinician documents consent and verifies absence of severe illness (SAGE queries in CIS)
- SAGE checks for any vaccine deferral reasons
- In Carecast, Inbox message sent:
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- Nurse administers vaccines and documents care
Patient: Yura Sage

- 36 year old Caucasian female
- Allergies: Penicillin
- Problems: Hypertension, rheumatoid arthritis, nasal allergies, chronic bronchitis, history of splenectomy
- Medications: Cytoxan 50mg (alkylating agent), Celebrex 200mg
- Vaccination History:
  - 1 dose Pneumococcal (PPV23)vaccine (last dose 2000)
  - 2 doses Diphtheria containing vaccine
  - 1 dose Hepatitis B vaccine
SAGE Triggering Event:
‘Outpatient nurse accesses the patient record’
SAGE Triggering Event:
‘Outpatient nurse accesses the patient record’
SAGE Triggering Event:
‘Outpatient nurse accesses the patient record’
SAGE Server Log:
Carecast Event Notification

execute local call
setting config...
  params...
  SAGE_KEY=1:null
  PATIENT_ID=1
  INTERNAL_ID=null
  CLEAR_STATES=true
  ORIGINAL_EVENT=admin
  EVENT=admin
  GUIDELINE_ID=null
  AUDIT=
  done config
arg: -pid=01000214
arg: -hostname=iasage01
arg: -event=Outpatient nurse accesses patient record
arg: -local
arg: -iid=
params...
  Outpatient nurse accesses patient record
context 00000m: Nurse Updates Medical Record
context 00000m: Compute vaccine eligibility
  evaluate: 1148116403097 >= 19.0YEARM
  criterion 02469ms: AGE >= 19 YEAR result=true pid=01000214 gid=4
evaluate: 1148116403113 < 19.0YEARM
  criterion 00016ms: age < 19 years result=false pid=01000214 gid=4
evaluate: 1148116403128 >= 19.0YEARM
  criterion 00015ms: AGE >= 19 YEAR result=true pid=01000214 gid=4
decision 02500ms: Determine eligibility by age
  evaluate: 1148116403144 >= 19.0YEARM
  criterion 00016ms: AGE >= 19 YEAR result=true pid=01000214 gid=4
context 00016m: Adult immunization subguideline
SAGE Server Log:
Carecast Event Notification

execute local call
setting config...
  params...
  SAGE_KEY=1;null
  PATIENT_ID=1
  INTERNAL_ID=null
  CLEAR_STATES=true
  ORIGINAL_EVENT=admin
  EVENT=admin
  GUIDELINE_ID=null
  AUDIT=
done config
arg: --pid=01000214
arg: --hostname=iasage01
arg: --event=Outpatient nurse accesses patient record
arg: --local
arg: --iid=
  params...
  Outpatient nurse accesses patient record
context 00000ms: Nurse Updates Medical Record
context 00000ms: Compute vaccine eligibility
  evaluate: 1146116403097 >= 19.0YEAR
criterion 02469ms: AGE >= 19 YEAR result=true pid=01000214 gid=4
  evaluate: 1146116403110 < 19.0YEAR
criterion 00015ms: age < 19 years result=true pid=01000214 gid=4
  evaluate: 1146116403128 >= 19.0YEAR
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execute local call
setting config...
  params...
  SAGE_KEY=1:null
  PATIENT_ID=1
  INTERNAL_ID=null
  CLEAR_STATES=true
  ORIGINAL_EVENT=admin
  EVENT=admin
  GUIDELINE_ID=null
  AUDIT=
done config
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arg: -local
arg: -iid=

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SAGE Queries Record: Problem List and Active Orders
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SAGE Queries Record: Problem List and Active Orders

criterion 00016Ms: Record of PPV23 administration is not present (0) result=false pid=01000214 gid=4
  evaluate: true AND false

criterion 00062Ms: PPV23 first dose indicated (adult) result=false pid=01000214 gid=4
  evaluate: 1 equals 1

criterion 00000ms: # of PPV23 = 1 result=true pid=01000214 gid=4

criterion 00000ms: Chronic renal failure result=false pid=01000214 gid=4

criterion 00000ms: Nephrotic syndrome result=false pid=01000214 gid=4
  evaluate: false OR false

criterion 00000ms: Cochlear implant problem history result=false pid=01000214 gid=4

criterion 00016ms: Functional asplenia result=false pid=01000214 gid=4

criterion 00000ms: Congenital asplenia result=false pid=01000214 gid=4
  evaluate: false OR false

criterion 00000ms: Sickle cell disease result=false pid=01000214 gid=4

criterion 00000ms: Asplenia syndrome result=false pid=01000214 gid=4
  evaluate: false OR false

criterion 00000ms: Hemoglobinopathy result=false pid=01000214 gid=4

criterion 00000ms: Splenectomy problem history result=true pid=01000214 gid=4

criterion 00016ms: Functional or anatomic asplenia result=true pid=01000214 gid=4

criterion 00000ms: Pneumococcal (PPV23) revaccination high risk loss of immunity indications (. result=false pid=1148115411003 >= 65.0YEAR

criterion 00015ms: AGE >= 65 YEAR result=false pid=01000214 gid=4
  evaluate: Wed Jun 07 00:00:00 CDT 2000 Before Mon Apr 30 00:00:00 CDT 2035

criterion 00016ms: last PPV23 vaccine given before age 65 result=true pid=01000214 gid=4
  evaluate: false AND true

criterion 00031ms: Age >= 65 years AND last PPV23 given < age 65 years result=false pid=01000214 gid=4
  evaluate: true OR false
SAGE Queries Record: Contraindications

criterion 0000ms: CSF leak result=false pid=01000214 gid=4
  evaluate: true = false

criterion 0000ms: Anaphylaxis reaction to Gelatin result=false pid=01000214 gid=4
  evaluate: true = false

criterion 0000ms: Anaphylaxis reaction to rubella vaccine result=false pid=01000214 gid=4
  evaluate: true = false

criterion 0000ms: Anaphylaxis reaction to measles vaccine result=false pid=01000214 gid=4

criterion 01140ms: Untreated active tuberculosis result=false pid=01000214 gid=4

criterion 01719ms: Congenital immunodeficiency result=false pid=01000214 gid=4

criterion 0000ms: HIV+ result=false pid=01000214 gid=4
  evaluate: false OR false

criterion 01734ms: Leukemia result=false pid=01000214 gid=4

criterion 02875ms: Lymphoma (includes Hodgkin's) result=false pid=01000214 gid=4

criterion 01250ms: Multiple myeloma result=false pid=01000214 gid=4

criterion 01219ms: Generalized Malignancy result=false pid=01000214 gid=4

criterion 01313ms: Bone marrow transplant recipient result=false pid=01000214 gid=4

criterion 01172ms: Immunodeficiency due to chemotherapy result=false pid=01000214 gid=4

criterion 00953ms: Antimetabolite therapy result=false pid=01000214 gid=4
  evaluate: 0 > 12

criterion 00761ms: Long term steroid therapy (12 glucocorticoid doses last six months) result=false pid=01000214 gid=4

criterion 01469ms: Solid organ transplant problem history result=false pid=01000214 gid=4

criterion 00656ms: Treatment with alkylating agent within last three months result=true pid=01000214 gid=4

criterion 15156ms: Immunosuppressive conditions result=true pid=01000214 gid=4

criterion 18953ms: MMR CONTRAINDICATIONS result=true pid=01000214 gid=4
  evaluate: NOT true

criterion 18969ms: MMR NOT contraindicated result=false pid=01000214 gid=4
SAGE Queries Record: Contraindications

criterion 0000Ms: CSF leak result=false pid=01000214 gid=4  
evaluate: true = false

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criterion 01219Ms: Generalized Malignancy result=false pid=01000214 gid=4  

criterion 01313Ms: Bone marrow transplant recipient result=false pid=01000214 gid=4  

criterion 01172Ms: Immune deficiency due to chemotherapy result=false pid=01000214 gid=4  

criterion 00953Ms: Antimetabolite therapy result=false pid=01000214 gid=4  
evaluate: 0 > 12

criterion 00751Ms: Long term steroid therapy (12 glucocorticoid doses last six months) result=false p  

criterion 08556Ms: Treatment with alkylating agent within last three months result=true pid=01000214 

criterion 18953Ms: KMR CONTRAINDICATIONS result=true pid=01000214 gid=4  
evaluate: NOT true

criterion 18969Ms: KMR NOT contraindicated result=false pid=01000214 gid=4
SAGE Recommendations

• Vaccines due but contraindicated
  – MMR
  – Varicella

• Vaccines due:
  – Hepatitis B
  – PPV23
  – MCV4
  – Influenza split virus
Inbox Notification
‘Due’ and ‘Contraindicated’ Vaccines

Outpatient Nurse Accesses Medical Record
Compute due immunizations
Vaccine due; required documents
Send notifications for any contraindicated vaccine

Notification: Patient message

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Subject</th>
<th>From</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Oct-06</td>
<td>09:12</td>
<td>Sage Message</td>
<td>USER, SAGE</td>
</tr>
<tr>
<td>2-Oct-06</td>
<td>09:12</td>
<td>Sage Message</td>
<td>USER, SAGE</td>
</tr>
</tbody>
</table>

subject: Send notification that MMR is contraindicated
message: MMR vaccine is due but contraindicated

subject: Send notification that varicella vaccine is contraindicated
message: Varicella vaccine is due but contraindicated

subject: Hep B due notification to report
message: Hep B vaccination is due
Inbox Notification

‘Due’ and ‘Contraindicated’ Vaccines

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subject: Send notification that MMR is contraindicated
message: MMR vaccine is due but contraindicated

subject: Send notification that varicella vaccine is contraindicated
message: Varicella vaccine is due but contraindicated

subject: Hep B due notification to report
message: Hep B vaccination is due
Inbox Notification
‘Due’ and ‘Contraindicated’ Vaccines

Outpatient Nurse Access Medical Record

- Send notifications for any contraindicated vaccine
- Compute for due immunizations
- Any immunization due?

Notification:
Patient message

<table>
<thead>
<tr>
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<th>FYI</th>
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</table>

subject: Send notification that MMR is contraindicated
message: MMR vaccine is due but contraindicated

subject: Send notification that varicella vaccine is contraindicated
message: Varicella vaccine is due but contraindicated

subject: Hep B due notification to report
message: Hep B vaccination is due

Reason for Forward/Reassign—
SAGE Queries Record: ‘Vaccines are due, request for documentation’

key

action sp: Generate Pneumococcal (PPV23) education material pid=01000214 gid=4
action sp: Pneumococcal (PPV23) vaccination actions pid=01000214 gid=4
criterion 00172ms: Influenza splitvirus vaccine is DUE result=true pid=01000214 gid=4
action sp: Generate Influenza [splitvirus] education material pid=01000214 gid=4
action sp: influenza splitvirus vaccination actions pid=01000214 gid=4
criterion 00171ms: Td vaccine is DUE result=false pid=01000214 gid=4
action sp: Td vaccination actions pid=01000214 gid=4
criterion 00188ms: DTaP vaccine is DUE result=false pid=01000214 gid=4
action sp: DTaP vaccination actions pid=01000214 gid=4
criterion 00281ms: PCV7 vaccine is DUE result=false pid=01000214 gid=4
action sp: Pneumococcal (PCV7) vaccination actions pid=01000214 gid=4
criterion 00172ms: Varicella vaccine is DUE result=false pid=01000214 gid=4
action sp: Varicella vaccination actions pid=01000214 gid=4
criterion 00172ms: MCV4 vaccine is DUE result=true pid=01000214 gid=4
action sp: Generate Meningococcal (MCV4) education material pid=01000214 gid=4
action sp: Meningococcal (MCV4) vaccination actions pid=01000214 gid=4
criterion 00172ms: Dt vaccine is DUE result=false pid=01000214 gid=4
action sp: DT vaccination actions pid=01000214 gid=4
criterion 00187ms: MPSV4 vaccine is DUE result=false pid=01000214 gid=4
action sp: Meningococcal (MPSV4) vaccination actions pid=01000214 gid=4
criterion 00172ms: Tdap vaccine is DUE result=false pid=01000214 gid=4
action sp: Tdap vaccination actions pid=01000214 gid=4
criterion 00188ms: Influenza wholevirus vaccine is DUE result=false pid=01000214 gid=4
action sp: Influenza wholevirus vaccination actions pid=01000214 gid=4
SAGE Queries Record:
‘Vaccines are due, request for documentation’

Outpatient Nurse Access Medical Record:
- Compute for Due Immunizations
- Send notifications for any contraindicated vaccine
- Check for any immunization due?
- Vaccines are due; request for documentation
- Place Orders for Due Vaccines

SAGE

Send notifications for any contraindicated vaccine

Vaccines are due; request for documentation

Place Orders for Due Vaccines

Outpatient Nurse Access Medical Record

Key

action sp: Generate Pneumococcal (PPV23) education material pid=01000214 gid=4
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criterion 00171ms: Td vaccine is DUE result=false pid=01000214 gid=4
action sp: Td vaccination actions pid=01000214 gid=4
criterion 00168ms: DTaP vaccine is DUE result=false pid=01000214 gid=4
action sp: DTaP vaccination actions pid=01000214 gid=4
criterion 00281ms: PCV7 vaccine is DUE result=false pid=01000214 gid=4
action sp: Pneumococcal (PCV7) vaccine actions pid=01000214 gid=4
criterion 00172ms: Varicella vaccine is DUE result=false pid=01000214 gid=4
action sp: Varicella vaccination actions pid=01000214 gid=4
criterion 00172ms: HAV vaccine is DUE result=false pid=01000214 gid=4
action sp: Generate Hepatitis A (HAV) education material pid=01000214 gid=4
action sp: Hepatitis A (HAV) vaccination actions pid=01000214 gid=4
criterion 00172ms: Diph vaccine is DUE result=false pid=01000214 gid=4
action sp: Diph vaccination actions pid=01000214 gid=4
criterion 00169ms: MPSV4 vaccine is DUE result=false pid=01000214 gid=4
action sp: Meningococcal (MPSV4) vaccination actions pid=01000214 gid=4
criterion 00172ms: Td vaccine is DUE result=false pid=01000214 gid=4
action sp: Td vaccination actions pid=01000214 gid=4
criterion 00167ms: Influenza wholevirus vaccine is DUE result=false pid=01000214 gid=4
action sp: Influenza wholevirus vaccination actions pid=01000214 gid=4

action 03455ms: Vaccines are due; request for documentation
SAGE Queries Record:
‘Vaccines are due, request for documentation’

SAGE,
Inbox Notification

‘Generate Vaccine Educational Material’

For Instance: Primary Care Immunizations

Label: Primary Care Immunizations

Description: Recommendation Set for outpatient immunizations (adult and pediatric patients)

Steps:
- Outpatient Nurse Access Medical Record
- Compute for Due Immunizations
- Send notifications for any contraindicated vaccine
- Vaccines are due, request for documentation
- Check for deferred vaccine

Date: 2006-06-01 12:00
Subject: Generate Influenza (H1N1) education material
From: USER, SAGE

Reason for Forward/Reassign:
Forwarded/Reassigned By USER, SAGE

Full Subject: Text: Sage Msg.
Inbox Notification
‘Generate Vaccine Educational Material’
Inbox Notification

‘Generate Vaccine Educational Material’

Outpatient Nurse Accesses Medical Record

- Compute for Due Immunizations
- Send notifications for any contraindicated vaccine

Vaccines are due, request for documentation

Check for deferred vaccine

Reason for Forward/Reassign:

Full Subject: Text, Sage Message

SAGE
Queries for Provider
‘Illness present?’, ‘Consent given?’
Queries for Provider
‘Illness present?’, ‘Consent given?’
Queries for Provider
‘Illness present?’, ‘Consent given?’
Queries for Provider
‘Illness present?’, ‘Consent given?’
SAGE Server Log

‘Finally Due’ Logic Evaluation

Check for Deferral Reasons
SAGE Server Log
‘Finally Due’ Logic Evaluation
Check for Deferral Reasons
SAGE Server Log
‘Finally Due’ Logic Evaluation
Check for Deferral Reasons

decision 00609ms: Is IPV (polio) finally due?
criterion 00187ms: ILLNESS PRESENT determined by care provider result=false
criterion 00188ms: Consent NOT GIVEN result=false pid=01000214 gid=4
evaluate: OR false
criterion 00203ms: Consent NOT GIVEN result=false pid=01000214 gid=4
evaluate: false OR false
evaluate: true = false
criterion 00390ms: Pneumococcal Vaccine should be DEFERRED result=false pid
criterion 00188ms: Pneumococcal (PPV23) is DUE result=true pid=01000214 gid
criterion 00219ms: ILLNESS PRESENT determined by care provider result=false
criterion 00187ms: Consent NOT GIVEN result=false pid=01000214 gid=4
evaluate: OR false
criterion 00187ms: Consent NOT GIVEN result=false pid=01000214 gid=4
evaluate: false OR false
evaluate: true = false
criterion 00000ms: anaphylaxis reaction to Latex result=false pid=01000214
criterion 00406ms: Pneumococcal Vaccine should be DEFERRED result=false pid
criterion 00203ms: PCV7 vaccine is DUE result=false pid=01000214 gid=4
decision 01187ms: Pneumococcal Vaccine finally due?
SAGE Server Log
‘Finally Due’ Logic Evaluation
Check for Deferral Reasons

decision 00609ms: Is IPV (polio) finally due?
  criterion 00187ms: ILLNES PRESENT determined by care provider result=false
  criterion 00183ms: Consent NOT GIVEN result=false pid=01000214 gid=4
    evaluate: OR false
  criterion 00205ms: Consent NOT GIVEN result=false pid=01000214 gid=4
    evaluate: false OR false
    evaluate: true = false

criterion 00000ms: Anaphylaxis reaction to Latex result=false pid=01000214
  criterion 00097ms: Pneumococcal Vaccine should be DEFERRED result=false pid=01000214
  criterion 00188ms: Pneumococcal (PPV23) is DUE result=true pid=01000214 gid=4
  criterion 00219ms: ILLNESS PRESENT determined by care provider result=false
  criterion 00187ms: Consent NOT GIVEN result=false pid=01000214 gid=4
    evaluate: OR false
  criterion 00187ms: Consent NOT GIVEN result=false pid=01000214 gid=4
    evaluate: true = false

  criterion 00000ms: Anaphylaxis reaction to Latex result=false pid=01000214
  criterion 00406ms: Pneumococcal Vaccine should be DEFERRED result=false pid=01000214
  criterion 00203ms: PCV7 vaccine is DUE result=false pid=01000214 gid=4

decision 01187ms: Pneumococcal Vaccine finally due?
SAGE Server Log

‘Place Orders for Due Vaccines’

criterion 00203ms: age < 19 years result=false pid=01000214 gid=4
criterion 00281ms: Hepatitis B vaccine is DUE result=true pid=01000214 gid=4
evaluate: false AND true
criterion 00484ms: Hep B vaccine is due and age < 19 years result=false pid=01000214 gid=4
action sp: Order Hep B Vaccine (children) pid=01000214 gid=4
criterion 00250ms: IPV vaccine is DUE result=false pid=01000214 gid=4
action sp: Order IPV (Polio) Vaccine pid=01000214 gid=4
criterion 00203ms: Hep A vaccine is DUE result=false pid=01000214 gid=4
action sp: Order Hep A Vaccine pid=01000214 gid=4
criterion 00319ms: Hib vaccine is due result=false pid=01000214 gid=4
action sp: Order Hib Vaccine pid=01000214 gid=4
criterion 00255ms: PCV7 vaccine is DUE result=false pid=01000214 gid=4
action sp: Order Pneumococcal 7-valent Conjugate Vaccine pid=01000214 gid=4
criterion 00203ms: Influenza wholevirus vaccine is DUE result=false pid=01000214 gid=4
action sp: Order Influenza wholevirus Vaccine pid=01000214 gid=4
criterion 00219ms: Pneumococcal (PPV23) is DUE result=true pid=01000214 gid=4
action sp: Order Pneumococcal 23-valent polysaccharide Vaccine pid=01000214 gid=4
criterion 00203ms: Td vaccine is DUE result=false pid=01000214 gid=4
action sp: Order Td Vaccine pid=01000214 gid=4
criterion 00203ms: DTP vaccine is DUE result=false pid=01000214 gid=4
action sp: Order DTap Vaccine pid=01000214 gid=4
criterion 00235ms: DT vaccine is DUE result=false pid=01000214 gid=4
action sp: Order DT Vaccine pid=01000214 gid=4
criterion 00203ms: Varicella vaccine is DUE result=false pid=01000214 gid=4
action sp: Order Varicella Vaccine pid=01000214 gid=4
SAGE Server Log

‘Place Orders for Due Vaccines’

criterion 00203ms: age < 19 years result=false pid=01000214 gid=4
criterion 00281ms: Hepatitis B vaccine is DUE result=true pid=01000214 gid=4 evaluate: false AND true
criterion 00484ms: Hep B vaccine is due and age < 19 years result=false pid=01000214 gid=4
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criterion 00250ms: IPV vaccine is DUE result=false pid=01000214 gid=4
action sp: Order IPV (Polio) Vaccine pid=01000214 gid=4
criterion 00203ms: Hep A vaccine is DUE result=false pid=01000214 gid=4
action sp: Order Hep A Vaccine pid=01000214 gid=4
criterion 00319ms: HiB vaccine is due result=false pid=01000214 gid=4
action sp: Order HiB Vaccine pid=01000214 gid=4
criterion 00255ms: PCV7 vaccine is DUE result=false pid=01000214 gid=4
action sp: Order Pneumococcal 7-valent Conjugate Vaccine pid=01000214 gid=4
criterion 00203ms: Influenza whole virus vaccine is DUE result=false pid=01000214 gid=4
action sp: Order Influenza whole virus Vaccine pid=01000214 gid=4
criterion 00219ms: Pneumococcal (PPV23) is DUE result=true pid=01000214 gid=4
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criterion 00203ms: Td vaccine is DUE result=false pid=01000214 gid=4
action sp: Order Td Vaccine pid=01000214 gid=4
criterion 00203ms: DTaP vaccine is DUE result=false pid=01000214 gid=4
action sp: Order DTaP Vaccine pid=01000214 gid=4
criterion 00235ms: DT vaccine is DUE result=false pid=01000214 gid=4
action sp: Order DT Vaccine pid=01000214 gid=4
criterion 00203ms: Varicella vaccine is DUE result=false pid=01000214 gid=4
action sp: Order Varicella Vaccine pid=01000214 gid=4
Place Orders for Due Vaccines

- Place Orders for Due Vaccines
- Check for any perinatal vaccine
- Send notifications for any contraindicated vaccine
- Compute for Due Immunizations

Criterions:
1. Hep B vaccine is DUE
   - Age < 19 years
   - Hep B Vaccine (children)
   - Order

2. IPV vaccine is DUE
   - Order IPV (Polio) Vaccine
   - Order

3. Hep A vaccine is DUE
   - Order Hep A Vaccine
   - Order

4. Hib vaccine is DUE
   - Order Hib Vaccine
   - Order

5. PCV7 vaccine is DUE
   - Order Pneumococcal 7-valent Conjugate Vaccine
   - Order

6. Influenza whole virus vaccine is DUE
   - Order Influenza whole virus Vaccine
   - Order

7. Pneumococcal (PPV23) is DUE
   - Order Pneumococcal 23-valent polysaccharide Vaccine
   - Order

8. Td vaccine is DUE
   - Order Td Vaccine
   - Order

9. DTaP vaccine is DUE
   - Order DTaP Vaccine
   - Order

10. DTP vaccine is DUE
    - Order DTP Vaccine
    - Order

11. Varicella vaccine is DUE
    - Order Varicella Vaccine
    - Order
4 Un-issued Orders to Resolve
4 Un-issued Orders to Resolve

<table>
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<tr>
<th>Status</th>
<th>Problem Description</th>
<th>Exp</th>
<th>Start Date</th>
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<td>Health care mainte...</td>
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<td>A</td>
<td>Hypertension</td>
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<tr>
<td>A</td>
<td>Chronic diabetes</td>
<td></td>
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<tr>
<td>A</td>
<td>Chronic bronchitis</td>
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- **Hepatitis B Vac Recombinant Syringe (10mcg/0.5ml)** IM pm 2-Oct-2006
- **Influenza Virus Vac Tr-Split Syringe IM IM pm** 2-Oct-2006
- **Meningococcal C conjugate vaccine IM pm** 2-Oct-2006
- **Pneumovax 23 Syringe (25mcg/0.5 ml) inj IM pm** 2-Oct-2006
- **Celebrex Cap (200mg) po PO Q AM #30 CAP ref** A 1-Jan-2006
- **Cyclophosphamide Tab (50mg) po PO BID #30 T** A 1-Apr-2006
- **Hepatitis B Recombinant Susp (20mcg/mL)** A 1-Jan-2004
- **Tetanus-Diphtheria Toxoids-To (5-2L) unit** IM L 25-May-2006
SAGE in Action!
Primary Care Visit Scenario
Patient: Yura Sage

- 36 year old Caucasian female
- Allergies: Penicillins
- Problems: Hypertension, rheumatoid arthritis, nasal allergies, chronic bronchitis, history of splenectomy
- Medications: **Cytoxan 50mg (alkylating agent)**, Celebrex 200mg
- Vaccination History:
  - 1 dose Pneumococcal (PPV23)vaccine
  - 2 doses Diphtheria containing vaccine
  - 1 dose Hepatitis B vaccine
SAGE in Action!
Primary Care Visit Scenario
Patient: Yura Sage

• Final vaccination orders recommended:
  - Pneumococcal (PPV23)
  - Hepatitis B
  - Meningococcal (MCV4)
  - Influenza split virus
Questions?

Discussion...