Analytics and Clinical Decision Support with SNOMED CT

Expo 2018 Tutorial

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SNOMED International

Overview

- Data analytics
  - Introduction
  - Preparing data
  - Techniques
  - Analytics tasks
  - Case studies
- Decision support
  - Introduction
  - Logical architecture
- Demonstration

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Introduction

Data Analytics

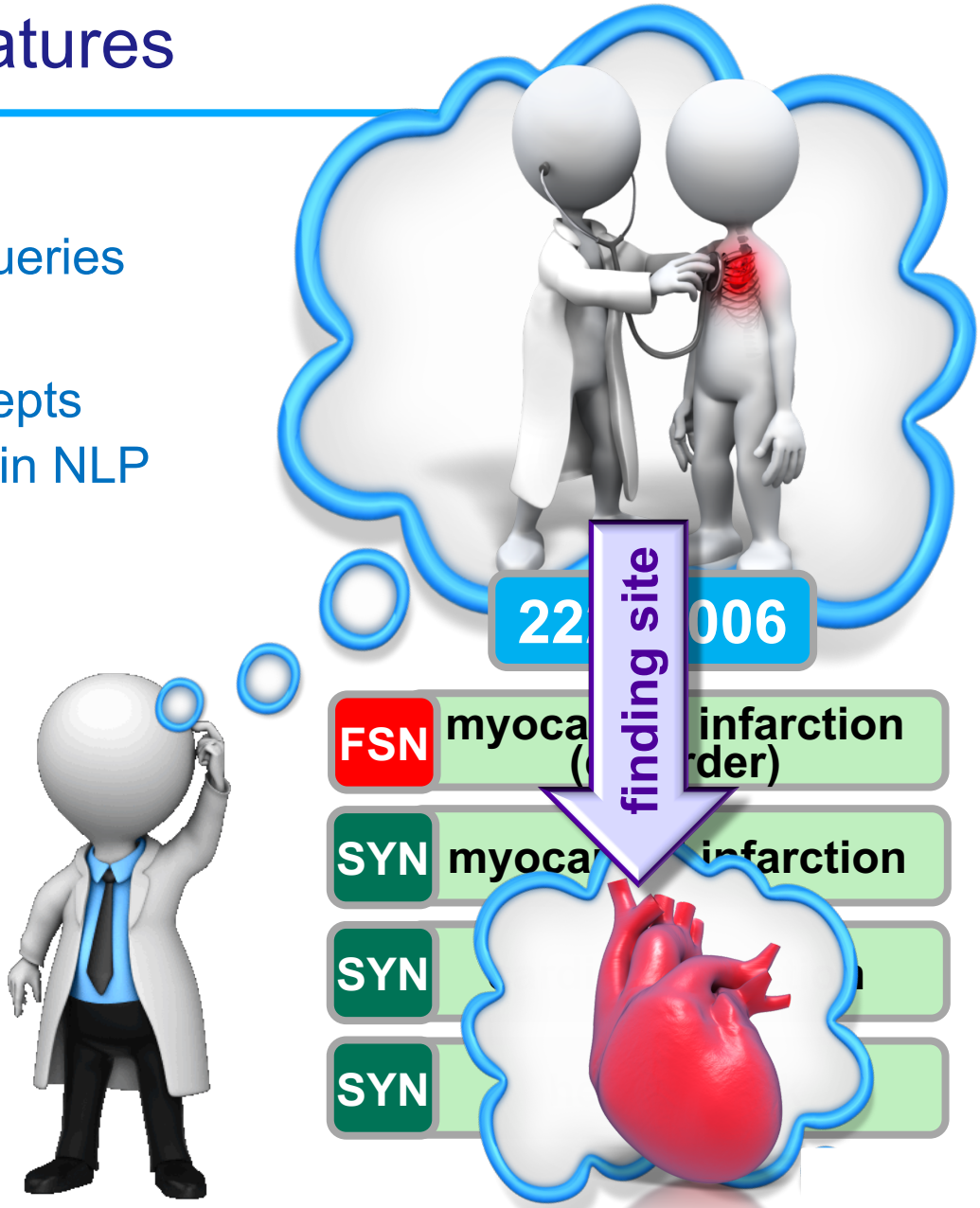
Discovery & communication of meaningful patterns in data

- May describe, predict and improve performance
- May recommend action or guide decision making
- Scope
  - Individual patients / healthcare workers
  - Patient groups / cohorts
  - Enterprise / geographic groups
- Substrate
  - Unstructured free text documents
  - Structured documents using SNOMED CT
  - Structured documents using other coding systems
  - Big data with a combination of the above

Purposes of Analytics

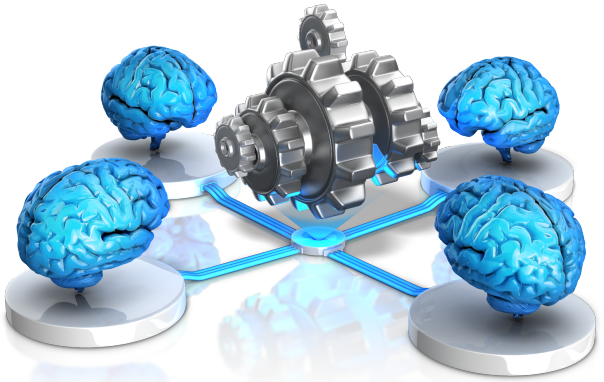
SNOMED CT Core Features

- Concepts
  - Enable meaning-based queries
- Descriptions
  - Assist searching for concepts
  - Enhance string-matching in NLP
  - Multi-lingual support
- Relationships
  - Support queries based on defined meaning
  - Aggregation
  - Query detailed content stored in EHRs using more abstract concepts



SNOMED CT Additional Features

- Concept Model
  - Provides rules for processing clinical meaning
- Expressions
  - Enable meaning-based queries over more than just concepts
- Reference sets
  - Represent subsets of concepts to help define query criteria
  - Represent non-standard aggregations for specific use cases
  - Define maps from other code systems to SNOMED CT
  - Define sets of language or dialect specific descriptions
- Description Logic
  - Supports computation of subsumption and equivalence



SNOMED CT Other Benefits

- Broad domain coverage
  - Enables queries across disciplines, specialties and domains
- Robust versioning
  - Helps to manage queries over longitudinal health records
- International
  - Enables queries, subsets, rules and maps to be shared and reused between countries
- Localization mechanisms
  - Allows queries to be applied to data from different countries, dialects, regions & applications

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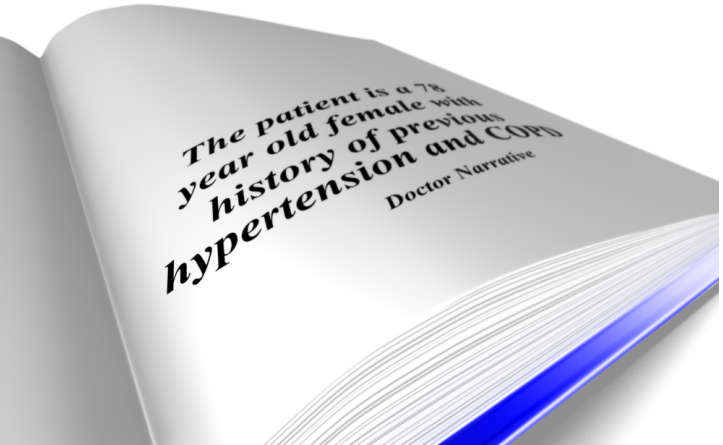
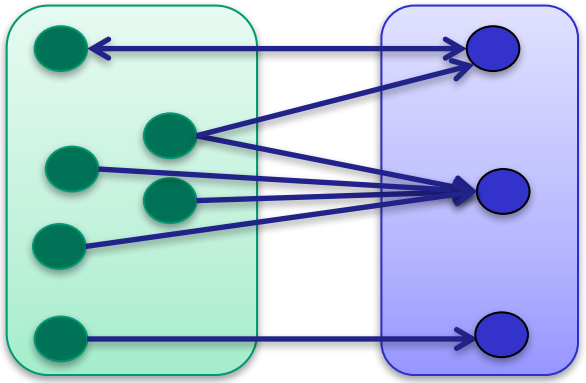
Data Analytics

Preparing Data for Analytics

Preparing Data for Analytics

1. Natural Language Processing
   - Enables a computer to extract meaning from human language
   - Automated coding requires manual review for reliable results
   - Context must be coded to ensure correct query results
2. Mapping Other Code Systems to SNOMED CT
   - SNOMED CT can be used as a common reference terminology for querying over data sources that use different coding systems
   - Direction and correlation of map effect the quality of analytics





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Data Analytics

Analytics Techniques

SNOMED CT Analytics Techniques

- Subsets
- Subsumption
- Defining relationships
- Expression constraints
- Description logic

Subsets

- Create subset of concepts for a specific clinical purpose
  - Manual inclusion using search and browse
  - Using an existing subset as a starting point
  - Lexical queries (string matching) to identify candidates
  - Hierarchical queries to select descendants of a concept
  - Attribute queries to find concepts with a specific attribute value
  - Expression constraint queries using a combination of features
- Subsets may be defined:
  - Extensionally – Flat list of concept identifiers
    - Distributed using a simple or ordered reference set
  - Intensionally – Using a machine processable query
    - Distributed using a query reference set
- Technique
  - Test each code in a patient's record for membership in subset

Subsets Example

Find patients with a tuberculosis disorder – e.g.

- Patient id: 1755
- Diagnosis: 38115001 |Tuberculosis of spinal meninges|

Subset: Tuberculosis disorders

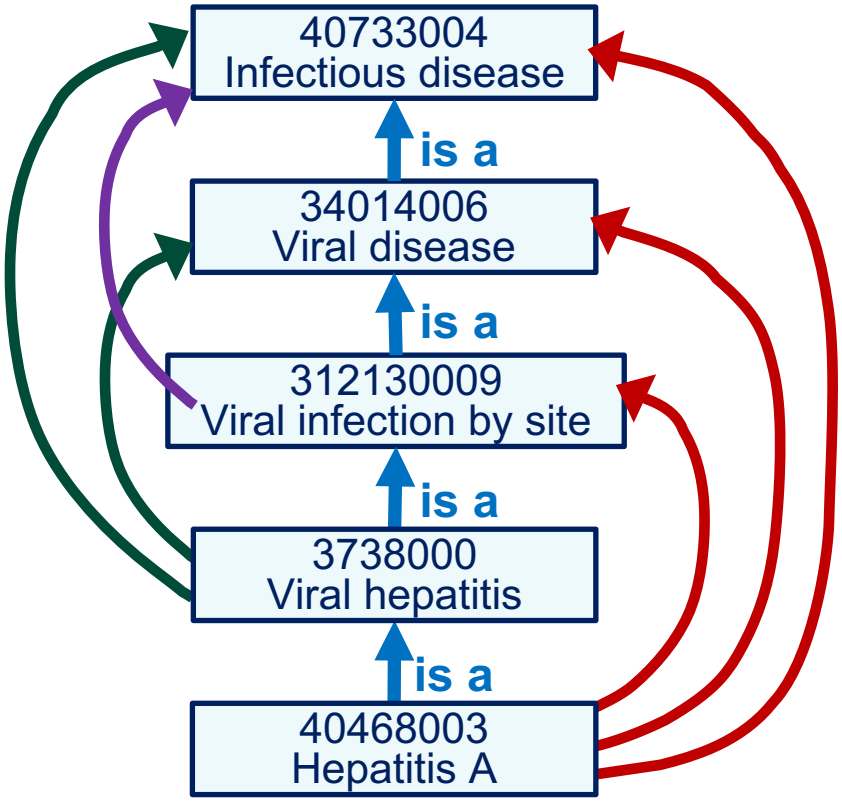
Concept ID	Description
56717001	tuberculosis (disorder)
58437007	tuberculosis of meninges (disorder)
90302003	tuberculosis of cerebral meninges (disorder)
38115001	tuberculosis of spinal meninges (disorder)
447332005	tuberculous abscess of epidural space (disorder)
11676005	tuberculous leptomeningitis (disorder)
447253004	tuberculous arachnoiditis (disorder)
31112008	tuberculous meningoencephalitis (disorder)

Subsumption

- Subsumption occurs when one clinical meaning is a subtype of another clinical meaning
  - Example - Which patients have an infectious disease?
    - Find patients with *any kind of* infectious disease - including
      - 75570004 |Viral pneumonia|
- Techniques
  - Precomputed transitive closure table
  - Using a Description Logic reasoner

Subsumption - Example

Hospital audit of patients with an infectious disease



Transitive Closure Table

sourceId	destinationId
34014006	40733004
312130009	34014006
3738000	312130009
40468003	3738000
40468003	40733004
40468003	34014006
40468003	312130009
3738000	40733004
3738000	34014006
312130009	40733004
415353009	40733004
75570004	40733004

Subsumption - Example

Hospital Audit for Patients with Infectious Disease

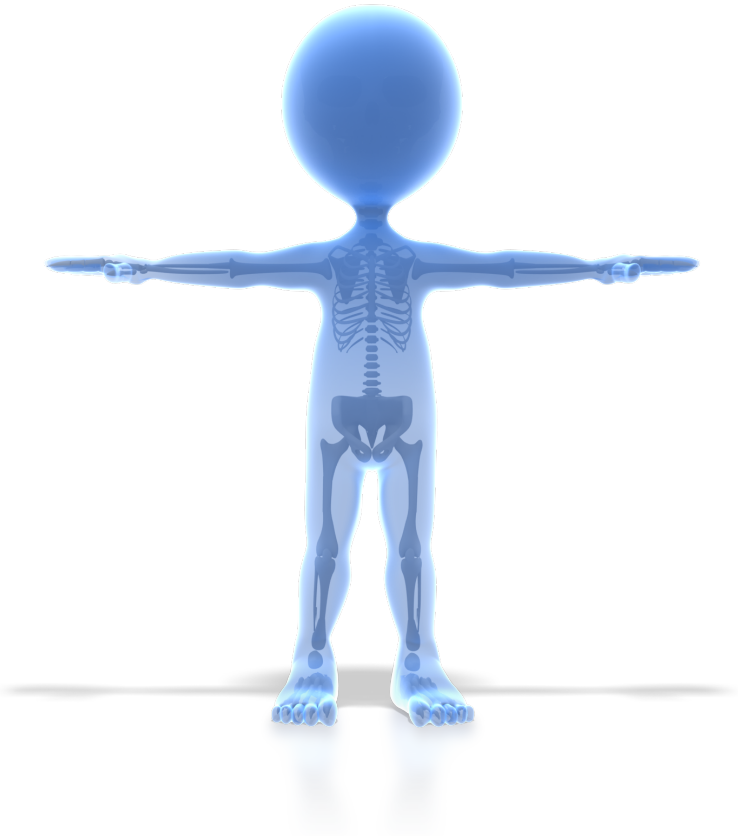
```
SELECT * FROM health_records
WHERE diagnosis = (subtypeOf
      40733004 |Infectious disease|)
```

patient	Diagnosis
Bill	71620000 |Fracture of femur|
Bill	40468003 |Hepatitis A|
Fred	66308002 |Fracture of humerus|
Mary	415353009 |Rotavirus food poisoning|
Bob	75570004 |Viral pneumonia|
Susan	22298006 |Myocardial infarction|
Susan	195967001 |Asthma|

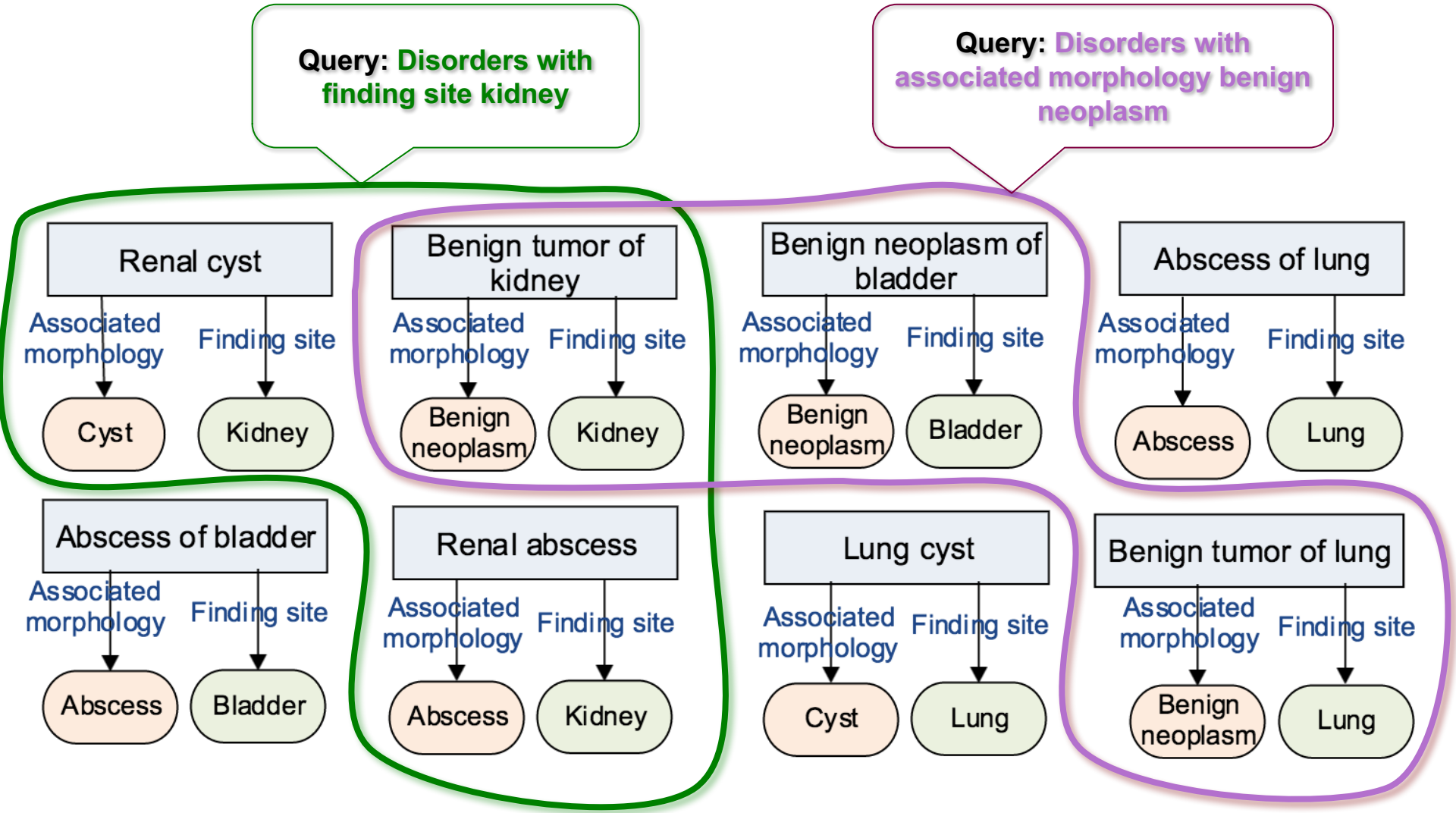
subtype	supertype
34014006	40733004
312130009	34014006
3738000	312130009
40468003	3738000
40468003	40733004
40468003	34014006
40468003	312130009
3738000	40733004
3738000	34014006
312130009	40733004
415353009	40733004
75570004	40733004

Defining Relationships

- Represent a characteristic of the meaning of a concept
- More than 100 attributes, including
  - 363698007 |Finding site|
  - 116676008 |Associated morphology|
  - 246075003 |Causative agent|
  - 363704007 |Procedure site|
  - 260686004 |Method|
  - 272741003 |Laterality|
- Concept Model provides rules
- Techniques
  - Using the distributed Relationships file
  - Using a Description Logic Reasoner



Defining Relationships - Example



Expression Constraints

- A computable rule that can be used to define a bounded set of clinical meanings
  - Example: *Lung disorders with morphology a type of edema*

< 19829001 |disorder of lung| :

116676008 |associated morphology| = << 79654002 |edema|

Concept Id	Term
233709006	Toxic pulmonary edema
11468004	Postoperative pulmonary edema
19242006	Pulmonary edema
61233003	Silo-fillers' disease
40541001	Acute pulmonary edema
89687005	Postimmersion-submersion syndrome
67782005	Adult respiratory distress syndrome

Expression Constraints

Symbol	Name
<	Descendant of
<<	Descendant or self of
>	Ancestor of
>>	Ancestor or self of
<!	Child of
^	Member of
*	Any
AND	Conjunction
OR	Disjunction
MINUS	Exclusion
[1..3]	Cardinality

Expression Constraints - Example

< 404684003 |Clinical finding|:
116676008 |Associated morphology| = << 3898006 |Benign neoplasm|
AND 363698007 |Finding site| = << 64033007 |Kidney structure|

Concept ID	Preferred Term
254925008	Benign tumor of renal calyx
254919009	Cortical adenoma of kidney
269489006	Benign tumor of renal parenchyma
254920003	Cystadenoma of kidney
254922006	Oncocytoma of kidney
276866009	Benign tumor of pelviureteric junction
254927000	Benign papilloma of renal pelvis
92319008	Benign neoplasm of renal pelvis
307618001	Juxtaglomerular tumor
254923001	Hemangiopericytoma of kidney
254921004	Angiomyolipoma of kidney
92165001	Benign neoplasm of kidney

Expression Constraints - SNOMED CT Browser

Concept Details | Expression Constraint Queries

Terminology content selections

Enter an expression

Clear Help

Enter an existing expression

```
< 404684003 |Clinical finding|:
116676008 |Associated morphology| = << 3898006 |Benign neoplasm|
AND 363698007 |Finding site| = << 64033007 |Kidney structure|
```

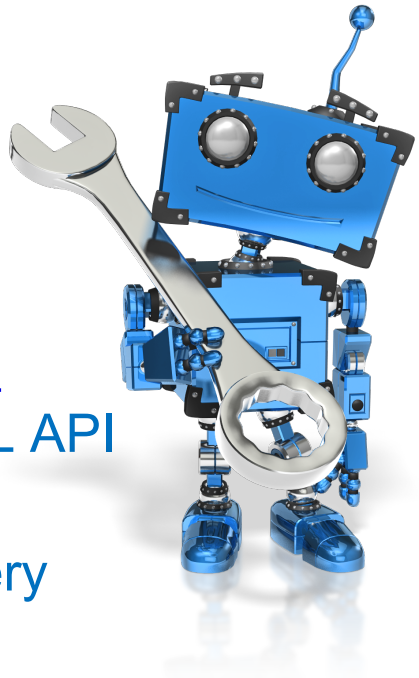
Execute

Results: Found 17 concepts

Concept	Id
Angiomyolipoma of bilateral kidneys (disorder)	15638291000119105
Oncocytoma of right kidney (disorder)	1081241000119107
Oncocytoma of left kidney (disorder)	1081231000119103
Angiomyolipoma of right kidney (disorder)	1079001000119106
Angiomyolipoma of left kidney (disorder)	1078991000119106
Juxtaglomerular tumor (disorder)	307618001

Description Logic

- SNOMED CT semantics are based on Description Logic
- This enables
  - The automation of reasoning across SNOMED CT
  - The implementation of more powerful analytics operations
    - Testing subsumption between concepts and expressions
    - Inferring new defining relationships
    - Transitive properties and property chaining
    - Reasoning with concrete values and GCIs
- Technique
  - Translate SNOMED CT into OWL 2
    - Snomed-owl-toolkit at http://github.com/IHTSDO
  - Load OWL files into DL enabled service or use OWL API
  - Use DL reasoner – e.g. FACT++, ELK, Snorocket
  - Semantic query languages – e.g. SPARQL, DL Query
  - Learn more – http://snomed.org/owl



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Data Analytics Tasks

SNOMED CT Analytics Tasks

Point of care analytics

Population based analytics

Clinical research

Point of Care Analytics

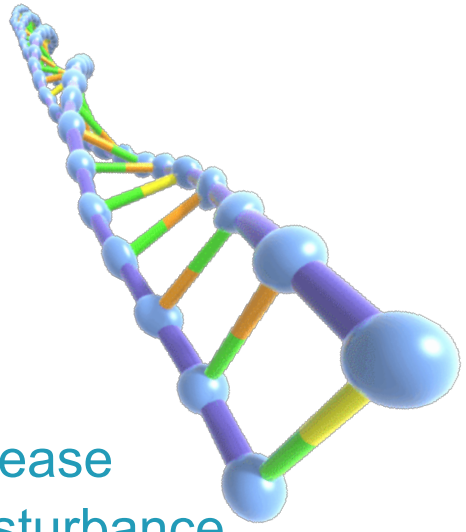
- Historical summaries
  - Summaries of a patient's clinical history
  - Aggregated from various institutions, models and code systems
- Point of care reporting
  - Helping clinicians remember preventative services (reminders)
  - Identifying patients with care gaps and risk factors
  - Monitoring patient compliance with prescribed treatments
  - Reporting clinical data to disease registries
- Clinical decision support
  - Presenting relevant clinical guidelines and care pathways
  - Alerts to increase patient safety
  - Diagnostic support tools and automated order sets

Population Analytics

- Trend analysis
  - Extracting underlying patterns or trends in data
  - Detect change in incidence or prevalence of a disease, treatment, procedure or intervention over time
  - Used for population health monitoring, predication of demand, and effective resource allocation
- Pharmacovigilance
  - Collection, detection, assessment, monitoring and prevention of adverse effects with pharmaceutical products
  - Queries over diseases, symptoms, lab results, medications, devices, procedures, allergies, adverse reactions and body sites
- Clinical audit
  - Improve patient care and outcomes through systematic review of care against defined standards and implementation of change
    - E.g. How many patients with ischemic heart disease are receiving appropriate drug treatments?

Clinical Research

- Identification of clinical trial candidates
  - For recruitment into formal clinical trials
  - E.g. Patients with disease of specific anatomical site or morphology
  - E.g. Patients taking medications with specific ingredients or forms
- Predictive medicine
  - Predicting the probability of disease and implementing measures to either prevent or significantly decrease its impact, such as
    - Lifestyle modifications
    - Increased surveillance
- Semantic search
  - Searching medical literature and clinical reports
  - Index collections of free text transcripts
  - Topic specific searching – e.g.
    - Find articles related to inflammatory bowel disease
    - Does patient's record suggest heart rhythm disturbance



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Data Analytics Case Studies

Kaiser Permanente (USA)

- Largest non-profit health plan in the USA
- KP HealthConnect uses SNOMED CT as the foundation for its clinical terminology (Convergent Medical Terminology – CMT)
- Scope
  - Used by clinicians to encode problem lists and other clinical information
  - Used to support KP's disease management programs
- Why SNOMED CT
  - Improved usability of the KP HealthConnect application
  - Efficient translation of business rules into Decision Support tools and performance measures used to support program
  - Support advanced analytics such as:
    - Identifying patient cohorts with certain conditions for population care
    - Identifying subsets for criteria in decision support modules
    - Finding conditions where causative agent is Aspergillus organism
    - Finding patients with diagnoses in cardiovascular disorders subset

Data Analysis & Reporting (Hong Kong)

- Hong Kong Hospital Authority manages public hospitals and services, including 42 hospitals, 48 specialist outpatient clinics and 73 general outpatient clinics
- Scope
  - Clinical terminology tables used by all clinical systems
  - Diagnosis, procedure, medication, laboratory, organisms
- Why SNOMED CT
  - Comprehensive domain coverage and underlying description logic
  - Interest in increasing decision support and data retrieval capabilities
  - Allows development of rich, criteria-based queries

Hong Kong Clinical Terminology Table (HKCTT)

SNOMED CT

ihtsdo

Diagnosis

Procedure

HKCTT

Drug

Laboratory

Others

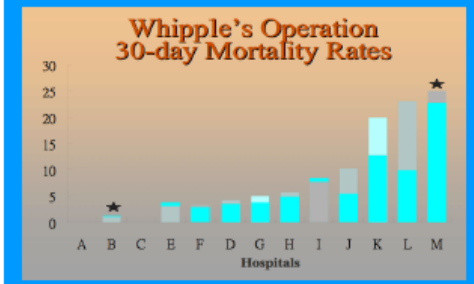
ICPC2

ICD 10

Registered Pharmaceutical Products

LOINC®

Secondary Use



Clinical Data Repository

eHR

eHR

OHDSI (US)

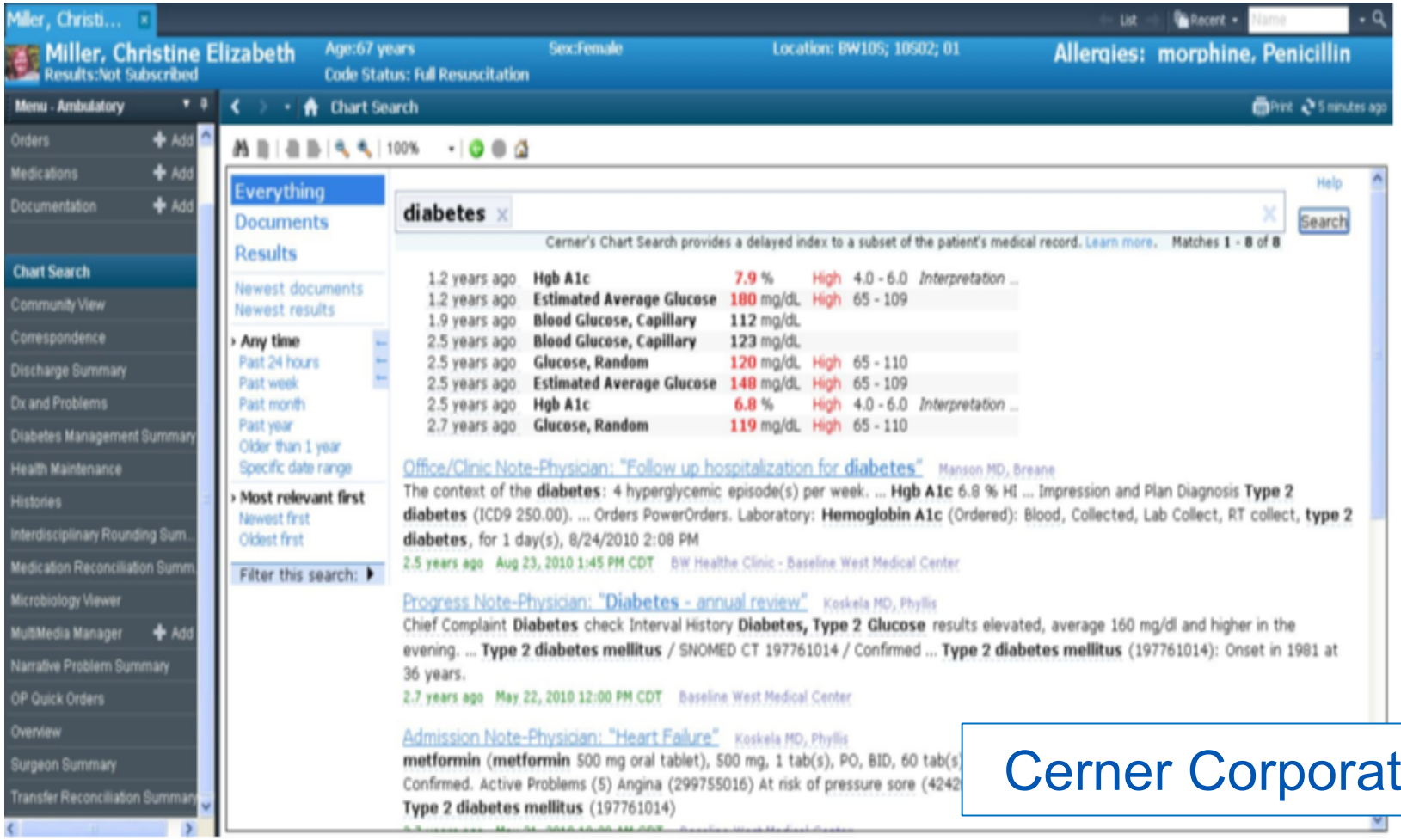
- Observational Health Data Sciences and Informatics
  - Large scale analytics of medical records over 40 databases containing observation data for over 500 million people
  - To better understand disease history, healthcare delivery and effects of medical interventions
  - Uses a Common Data Model – OMOP CDM
    - Integrates data using standardized structures and vocabulary
    - SNOMED CT used to integrate diagnostic and other data
  - http://www.ohdsi.org

OHDSI

OBSERVATIONAL HEALTH DATA SCIENCES AND INFORMATICS

Semantic Search Tool

- Searching clinical knowledge bases using SNOMED CT



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Clinical Decision Support

What is Clinical Decision Support?

- How does it enhance decision making?
  - Helps healthcare providers make
    - More informed decisions
    - Faster
- What information does it provide?
  - Supplies patient-specific information, guidance, and knowledge
- When can it be used?
  - At relevant points in the patient journey, such as
    - Diagnosis
    - Treatment
    - Follow-up

Types Of CDS

Alerts

Clinical guidelines / reference information

Conditional order sets / pathway support

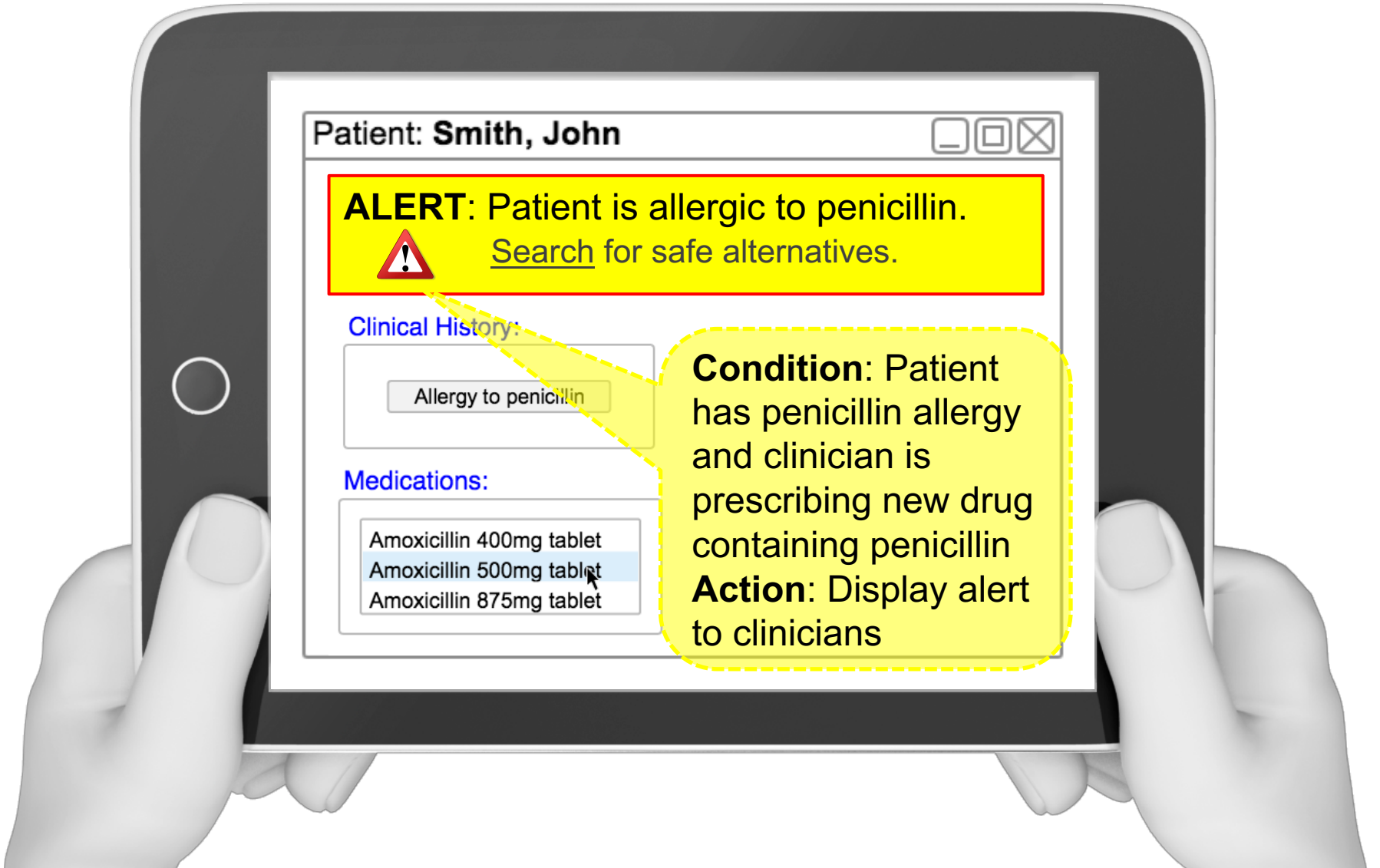
Automatically triggered reports or smart forms

Diagnostic support tools

Clinical Areas Where CDS is Used

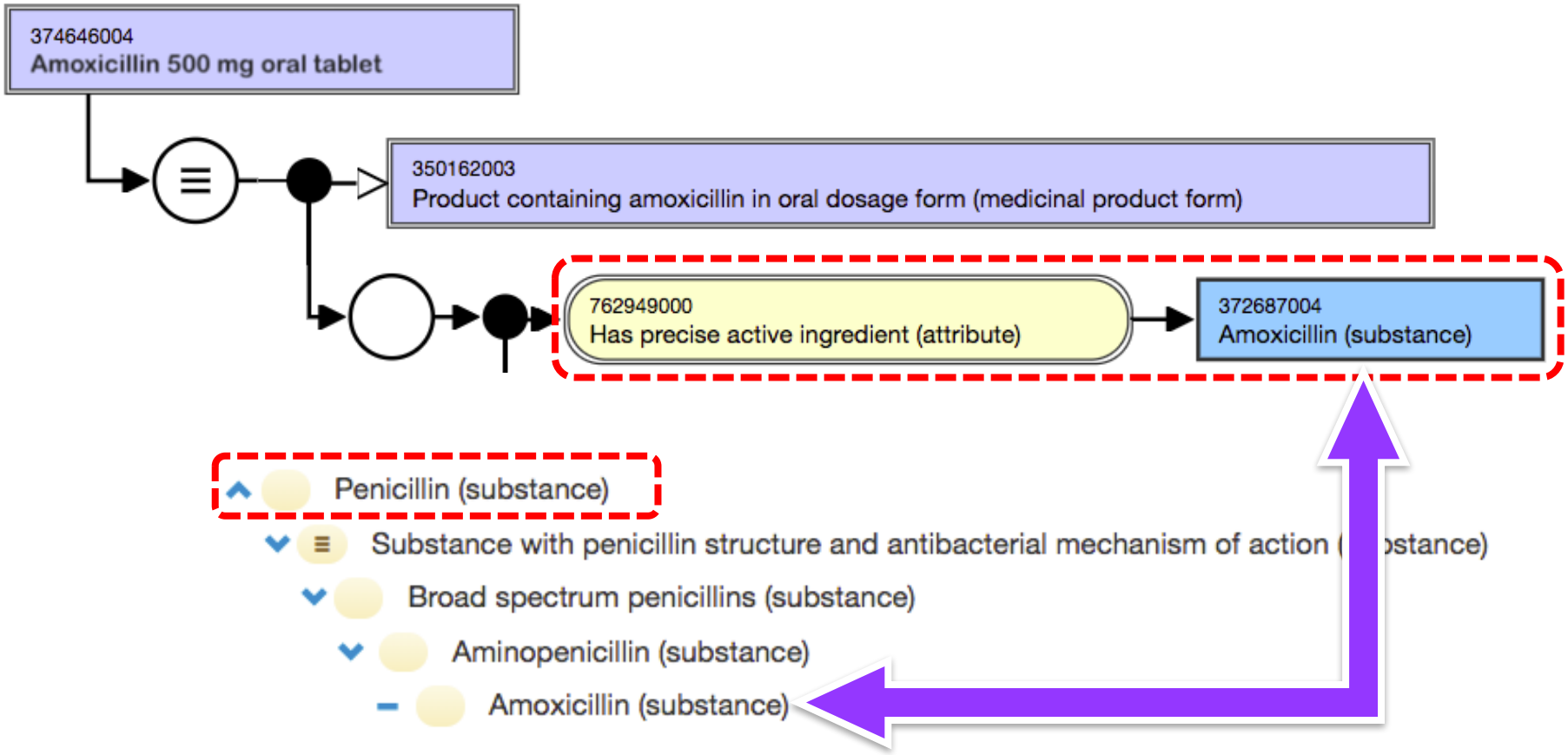
- Medication management
- Diagnosis (e.g. diabetes)
- Laboratory results
- Radiology
- Emergency department
- Infectious disease reporting
- Chronic asthma management
- Nursing interventions
- Clinical treatment audit (e.g. quality improvement)
- *And many more…*

CDS Example – Penicillin Allergy Alert



CDS Example – Penicillin Allergy Alert

< 373873005 |Pharmaceutical / biologic product|:
127489000 |Has active ingredient| = << 764146007 |Penicillin|



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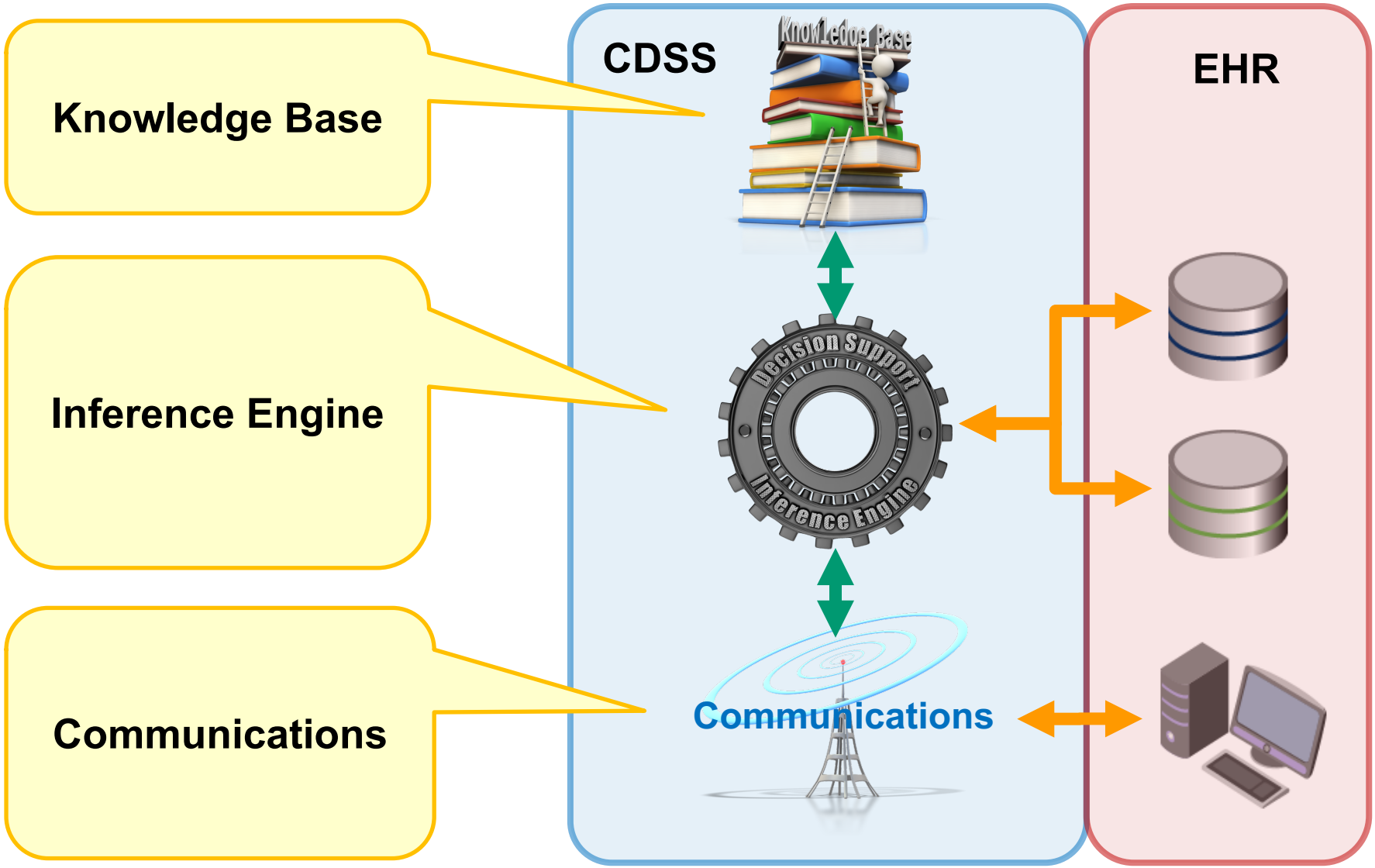
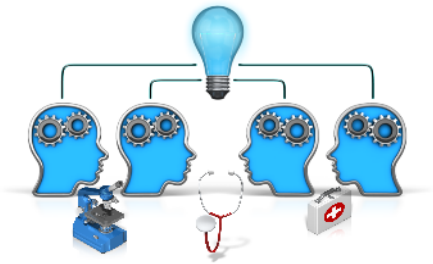
CDS Logical Architecture

Logical Architecture



Knowledge Base - The Brains

Clinical Knowledge



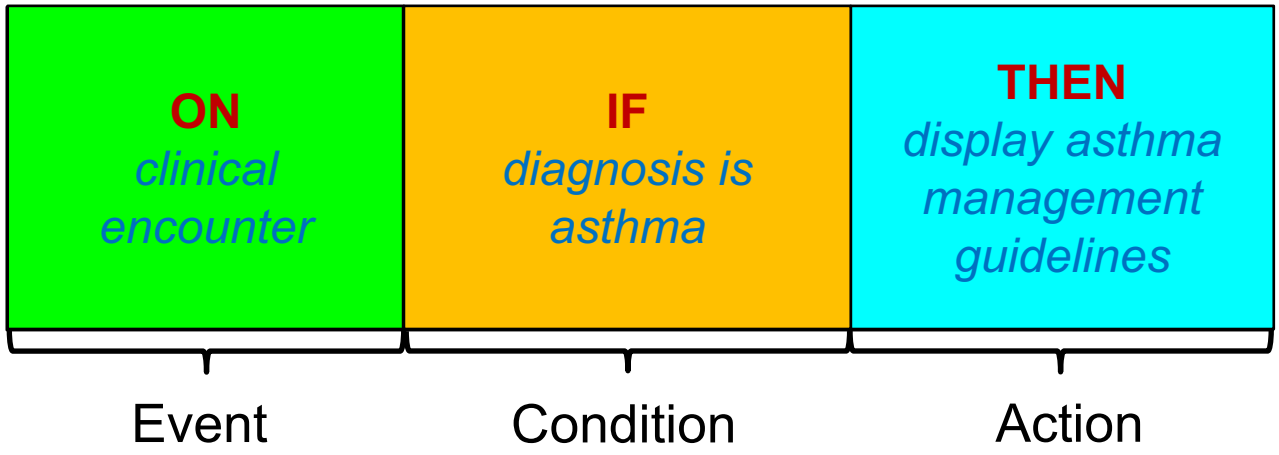
Load

Rules and Guidelines

Execute

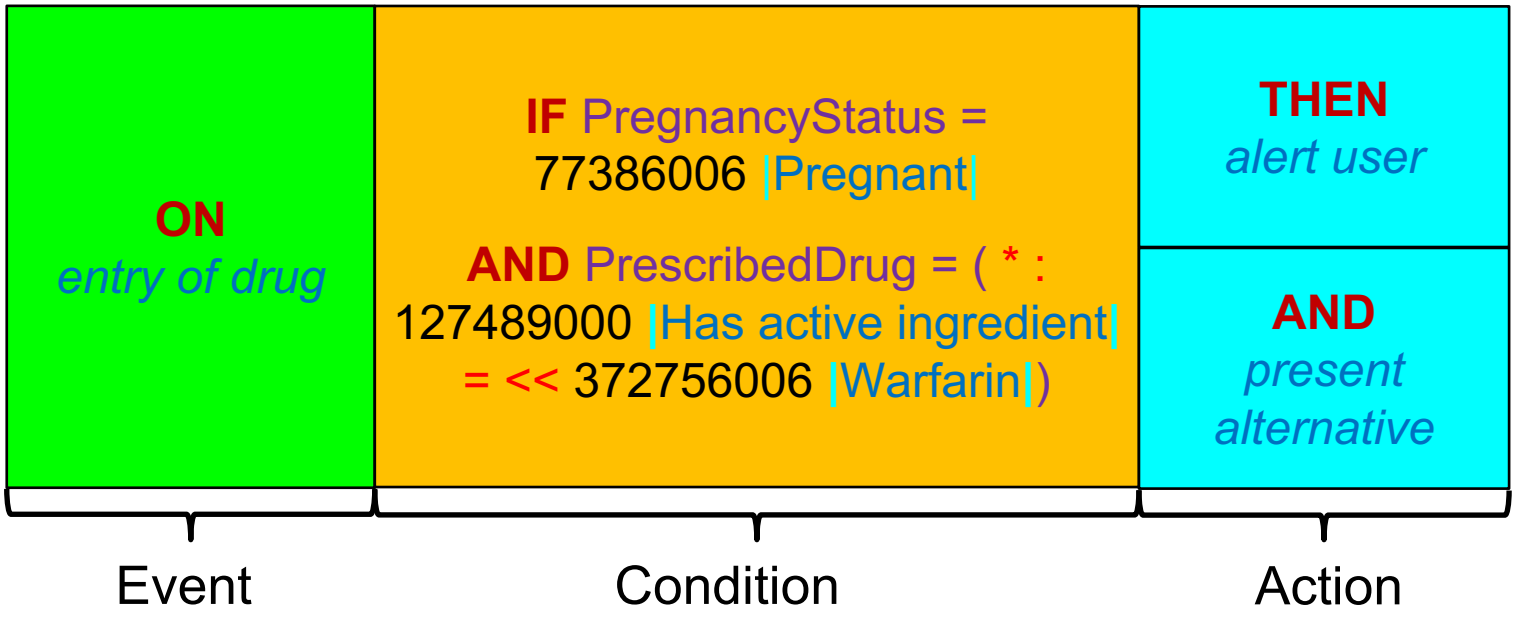
Inference Engine

Knowledge Base - Rules

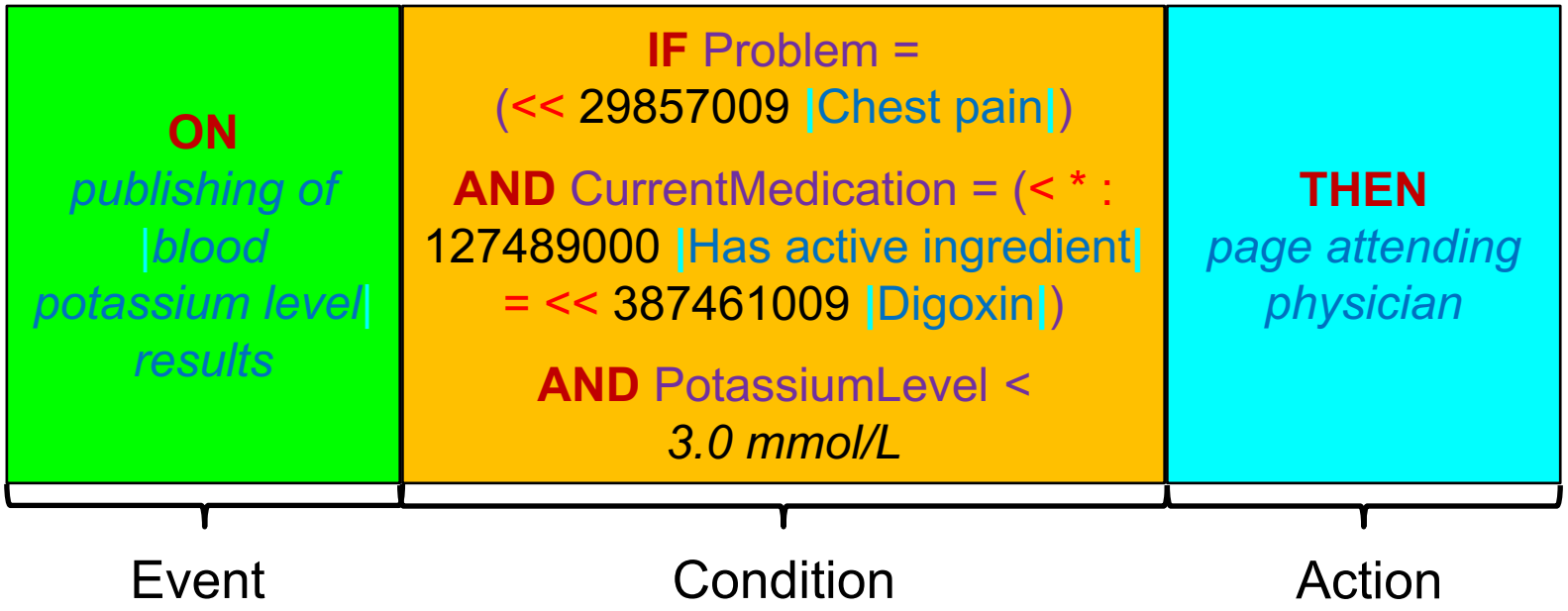


Note: Rules may reference both health records and terminology

Example Rule - Medication Order



Example Rule - Emergency Department



Linking Guidelines to SNOMED CT

SNOMED CT Semantic Tagging:

195967001 |Asthma (disorder)|
406162001 |Asthma management (regime/therapy)|
445531003 |Asthma control questionnaire (assessment scale)|

Document header (contains concept identifiers)

STEPWISE APPROACH FOR MANAGING ASTHMA LONG TERM

The stepwise approach tailors the selection of medication to the level of asthma severity (see page 5) or asthma control (see page 6). The stepwise approach is meant to help, not replace, the clinical decisionmaking needed to meet individual patient needs.

ASSESS CONTROL:

STEP UP IF NEEDED (first, check medication adherence, inhaler technique, environmental control, and comorbidities)

STEP DOWN IF POSSIBLE (and asthma is well controlled for at least 3 months)

	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6
At each step: Patient education, environmental control, and management of comorbidities						
0–4 years of age	**Intermittent Asthma**	**Persistent Asthma: Daily Medication** Consult with asthma specialist if step 3 care or higher is required. Consider consultation at step 2.				
Preferred Treatment†	SABA* as needed	low-dose ICS*	medium-dose ICS*	medium-dose ICS* + either LABA* or montelukast	high-dose ICS* + either LABA* or montelukast	high-dose ICS* + either LABA* or montelukast + oral corticosteroids
Alternative Treatment†‡		cromolyn or montelukast				
If clear benefit is not observed in 4–6 weeks, and medication technique and adherence are satisfactory, consider adjusting therapy or alternate diagnoses.						
Quick-Relief Medication	▪ SABA* as needed for symptoms; intensity of treatment depends on severity of symptoms. ▪ With viral respiratory symptoms: SABA every 4–6 hours up to 24 hours (longer with physician consult). Consider short course of oral systemic corticosteroids if asthma exacerbation is severe or patient has history of severe exacerbations. ▪ Caution: Frequent use of SABA may indicate the need to step up treatment.					

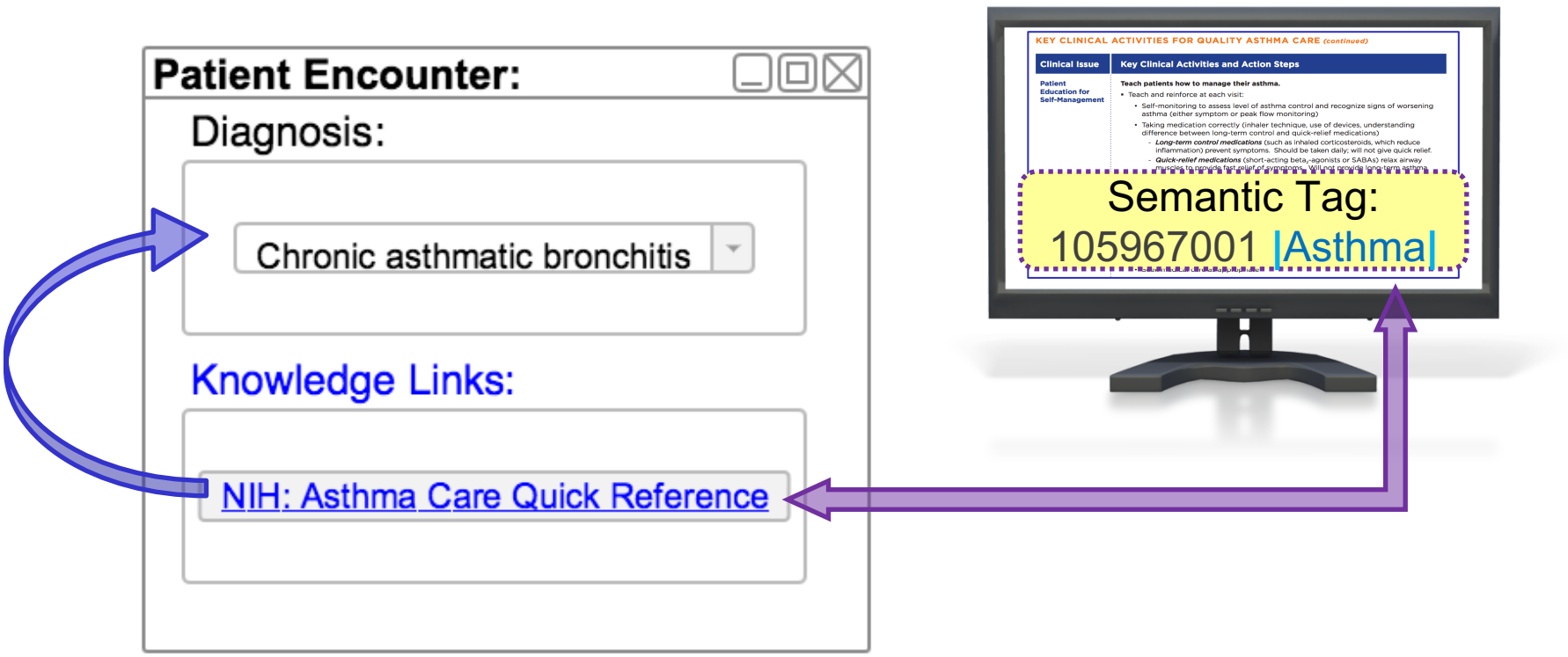
Document body (contains clinical guidelines)

*Asthma Care Quick Reference, Asthma Management Guideline (US Department of Health and Human Services, National Institutes of Health, National Heart Lung and Blood Institute)

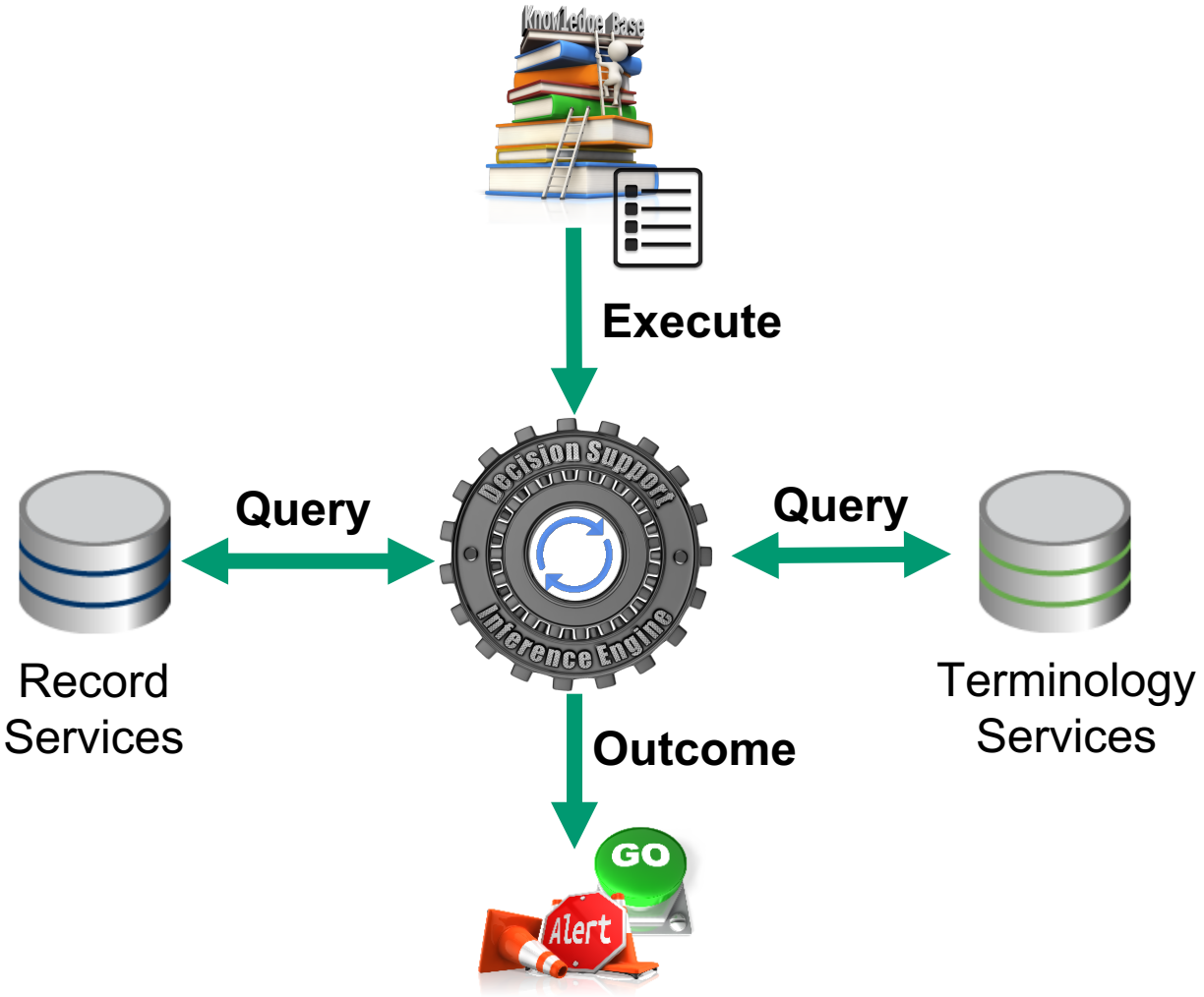
Selecting Relevant Guidelines

IF diagnosis **=<<** 195967001 |Asthma|

THEN display NIH: Asthma Care Quick Reference

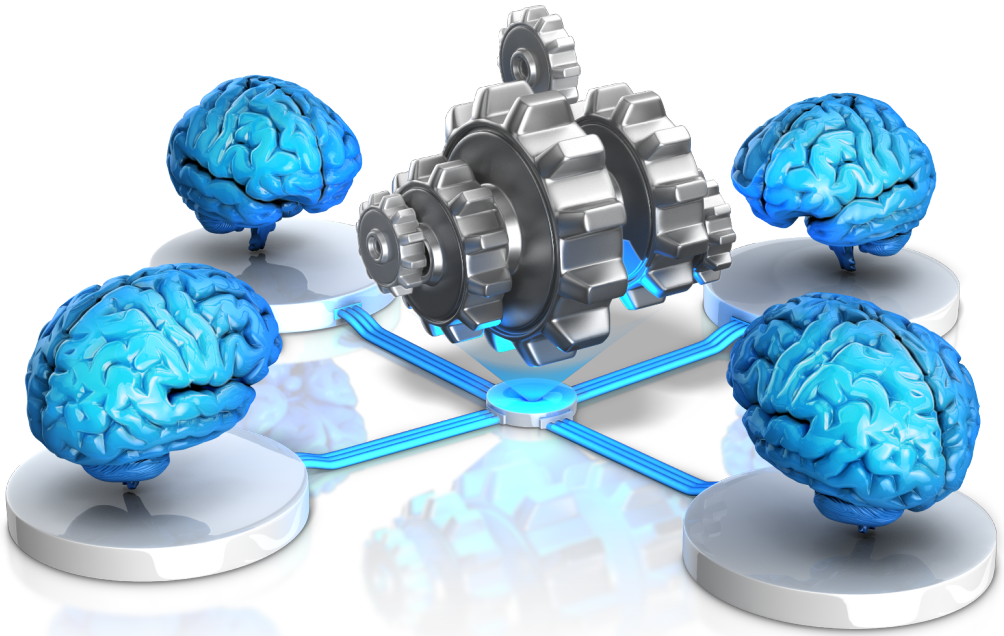


Inference Engine - The Heart

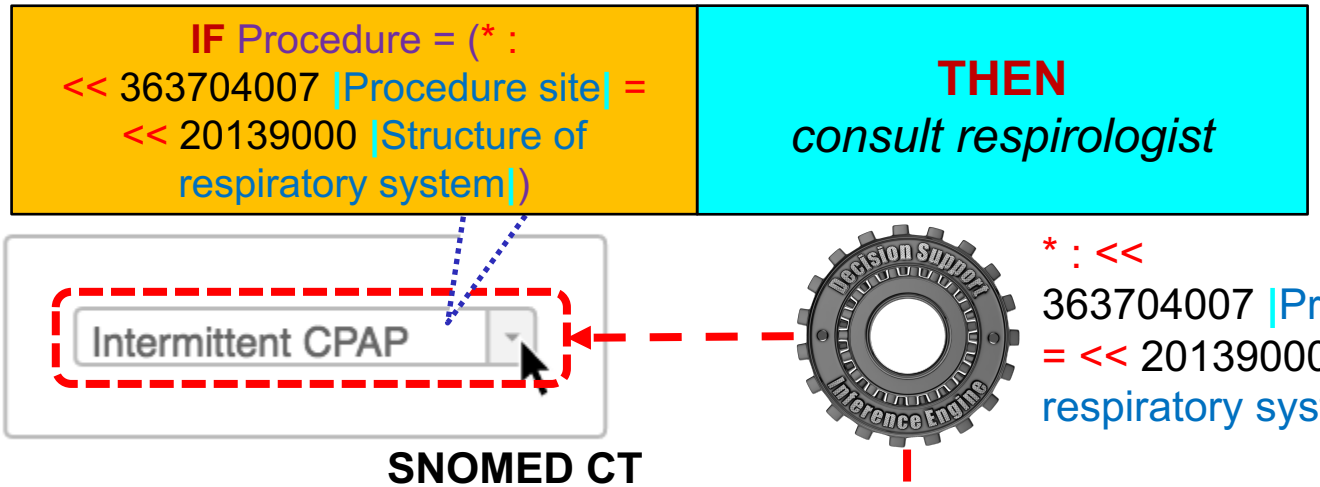


Inference Engine - Techniques

- *SNOMED CT analytics techniques used by inference engine to evaluate conditions in CDS rules*
  - Subsets
  - Subsumption
  - Defining relationships
  - Expression constraints
  - Description logic



Inference Engine - Example

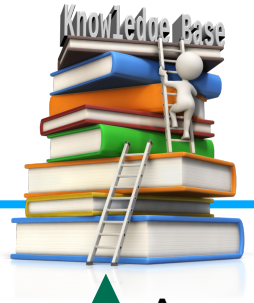


SNOMED CT
Inferred Relationships Table:

sourceId	destinationId	typeId
229308003	128258000	363702006
229308003	302803009	363702006
229308003	262202000	363703001
229308003	20139000	363704007
229308003	20139000	405813007
229308003	47545007	116680003
229308003	20139000	363704007

- Match:
  - Yes
- Condition:
  - True
- Action:
  - Triggered

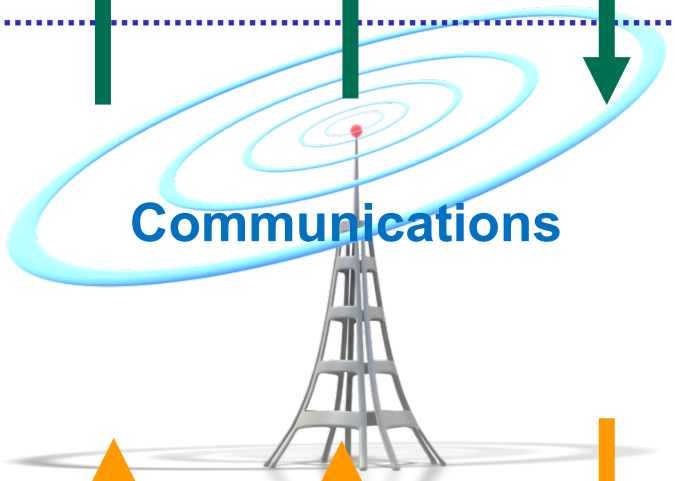
Communications - The Voice



Access CDS rule

Execution of CDS rule

ON	IF	THEN
event	*condition*	*action*

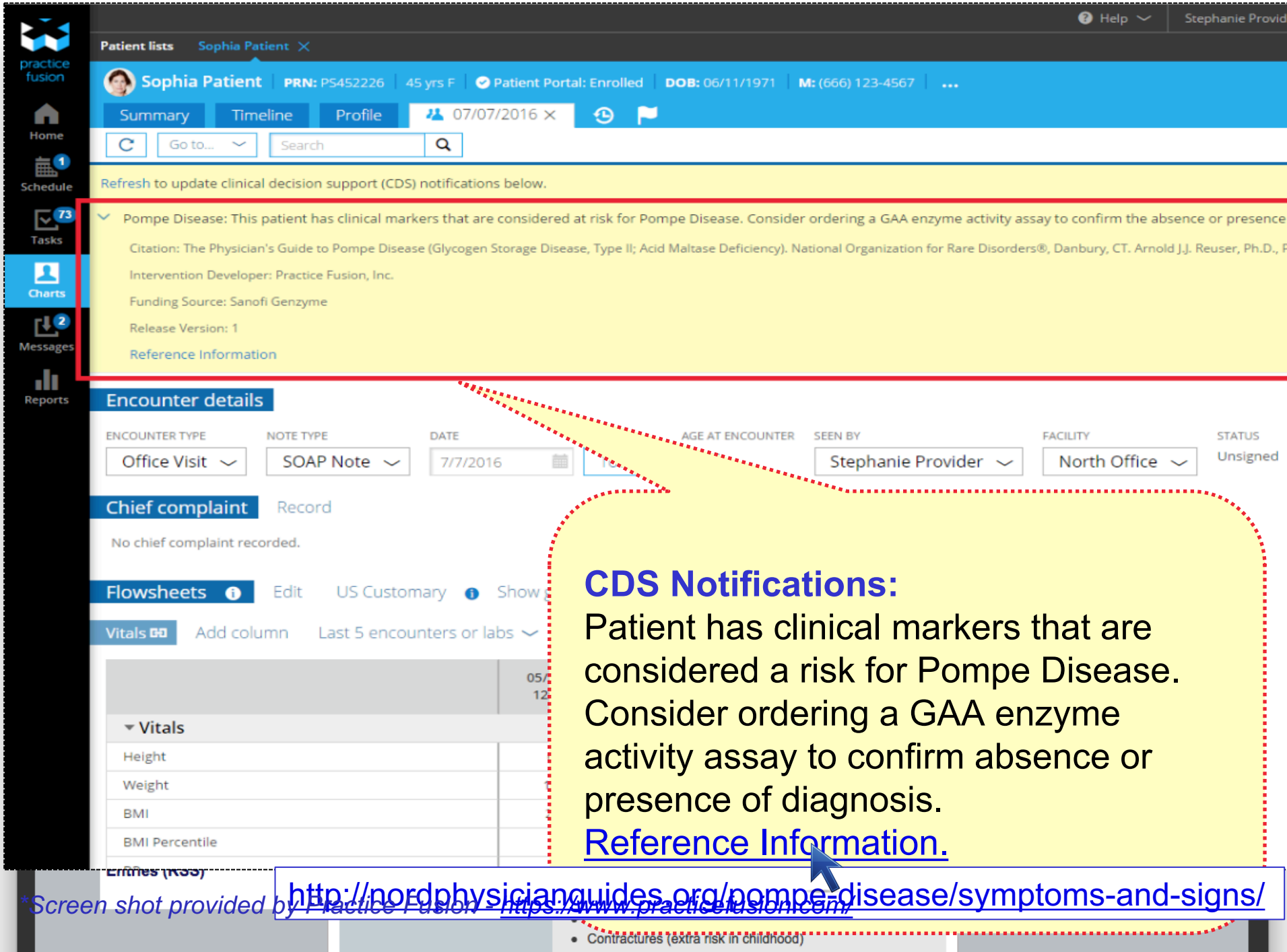


action

criterion values

event

User Interface



CDS Notifications:

Patient has clinical markers that are considered a risk for Pompe Disease. Consider ordering a GAA enzyme activity assay to confirm absence or presence of diagnosis.

Reference Information.

http://nordphysicianguides.org/pompe-disease/symptoms-and-signs/

*Screen shot provided by Practice Fusion - https://www.practicefusion.com/

Medline Plus Connect (USA)

An Infobutton resource used to request information from Medline Plus about the diagnosis (using SNOMED CT problem codes), medications, and lab tests in the record

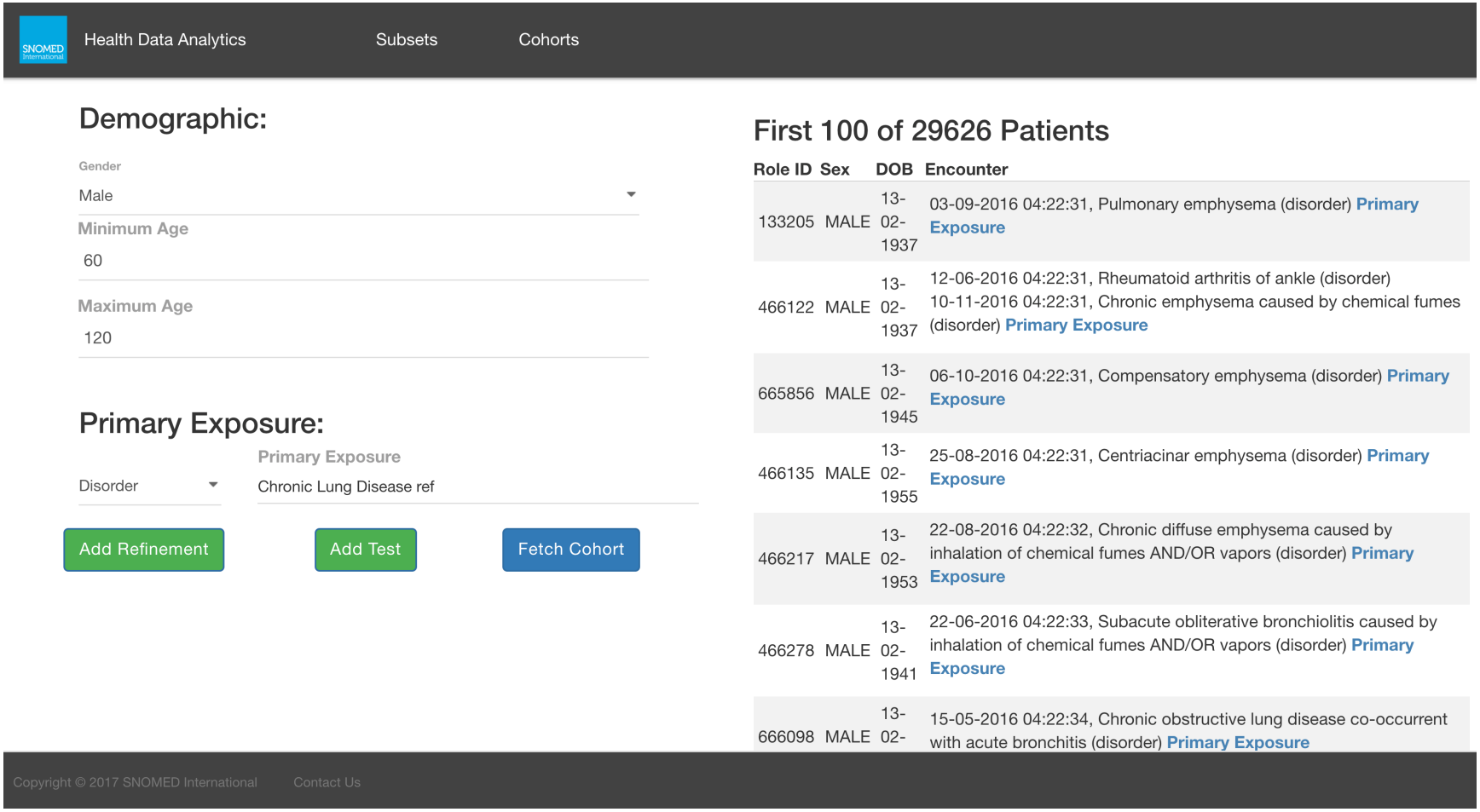
SNOMED International

Health Data Analytics Demonstration

Health Data Analytics

- SNOMED International demonstrator
  - Demonstrates use of SNOMED CT for data analysis
  - Database has over a million patients
  - Uses simulated clinical data
  - Scenarios tested on real clinical data with consistent results
- Demonstration
  - Using empirical evidence to determine best treatment
  - Scenarios
    - Rheumatoid arthritis and chronic obstructive pulmonary disease
    - Gastrointestinal disease and pulmonary embolism

Health Data Analytics Demonstration



Links to Further Information

- Data analytics with SNOMED CT
  - http://snomed.org/analytics
- Decision support with SNOMED CT
  - http://snomed.org/cds
- SNOMED CT languages
  - http://snomed.org/ecl
- E-Learning platform
  - http://snomed.org/elearning