


Analytics and Clinical Decision Support with SNOMED CT

Expo 2019 Tutorial


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SNOMED International





Overview

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






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

The diagram illustrates the purposes of analytics through three interconnected scenes. On the left, a doctor in a white coat examines a patient's chest with a stethoscope. In the center, a group of seven stylized human figures stands in a circle, with one figure in a dark suit and tie pointing towards the center, suggesting a collaborative meeting or analysis. On the right, a person in a white coat stands next to a large screen displaying a line graph with multiple colored lines, representing data analysis and reporting. Curved arrows connect these three scenes, indicating a flow of information and decision-making.

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

The diagram illustrates SNOMED CT Core Features. On the left, a doctor in a white coat examines a patient's chest with a stethoscope. In the center, a thought bubble contains a doctor and a patient, with a purple arrow pointing down to a list of SNOMED CT codes and descriptions. The list includes:

- 220006 finding site
- FSN myocardi (infarction disorder)
- SYN myocardi infarction
- SYN
- SYN

A red heart is shown at the bottom right, with a purple arrow pointing to it from the 'finding site' code. A person in a white coat and tie is shown at the bottom left, looking up at the thought bubble.

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





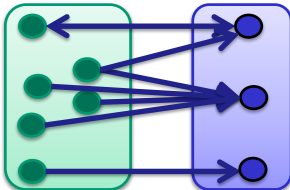
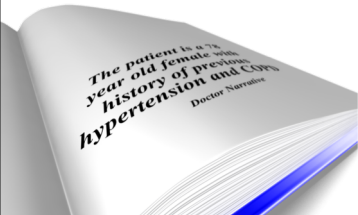
Data Analytics


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






Data Analytics

Analytics Techniques



SNOMED CT Analytics Techniques

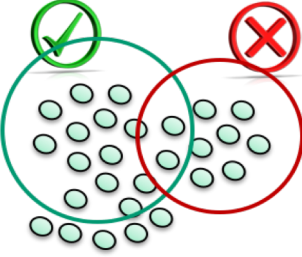
- Subsets
- Subsumption
- Defining relationships
- Expression constraints
- Description logic



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Subsets

- Create subset of concepts for a specific clinical purpose
 - Manual inclusion using search and browse
 - Use an existing subset as a starting point
 - Lexical query, hierarchical or attribute queries identify candidates
- Subsets may be defined
 - Extensionally – Flat list of concept identifiers
 - Intensionally – Using a machine processable query
- Technique
 - Test each code in a patient's record for membership in subset



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Subsets Example

Find patients with a tuberculosis disorder

- 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

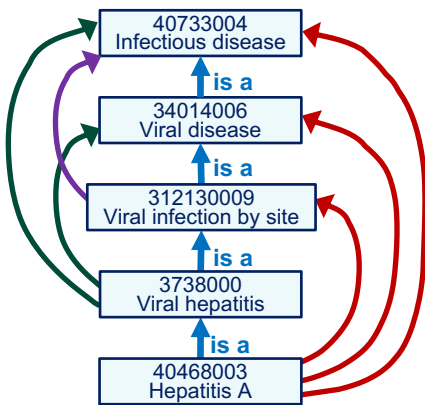
- Subsumption occurs when one clinical meaning is a subtype of another clinical meaning
 - Example - Which patients have an infectious disease?
 - Find patients with *any kind of* infectious disease - including
 - 75570004 |Viral pneumonia|
- Techniques
 - Precomputed transitive closure table
 - Exhaustive tree walk (in memory)
 - 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

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Subsumption - Example

Hospital Audit for Patients with Infectious Disease

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

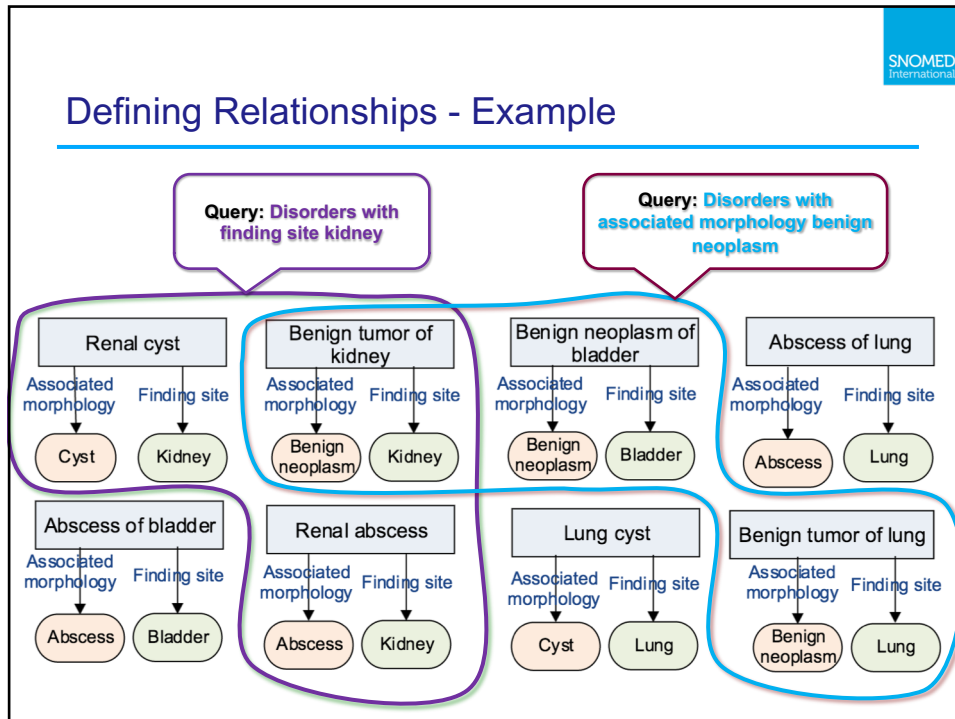
patient	Diagnosis
Bill	71620000 Fracture of femur
Bill	40468003 Hepatitis A
Fred	66308002 Fracture of humerus
Mary	415353009 Rotavirus food poisoning
Bob	75570004 Viral pneumonia
Susan	22298006 Myocardial infarction
Susan	195967001 Asthma

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

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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
 - Use the (inferred) Relationships file
 - Use the stated axioms with a description logic reasoner



Expression Constraints

- A computable rule that can be used to define a bounded set of clinical meanings (<http://snomed.org/ec/>)

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

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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	Juxtglomerular tumor
254923001	Hemangiopericytoma of kidney
254921004	Angiomyolipoma of kidney
92165001	Benign neoplasm of kidney

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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

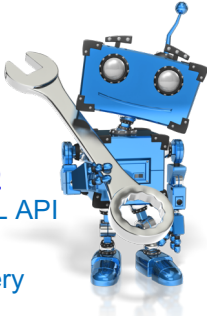
Results: Found 17 concepts


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
Juxtglomerular tumor (disorder)	307618001




Description Logic

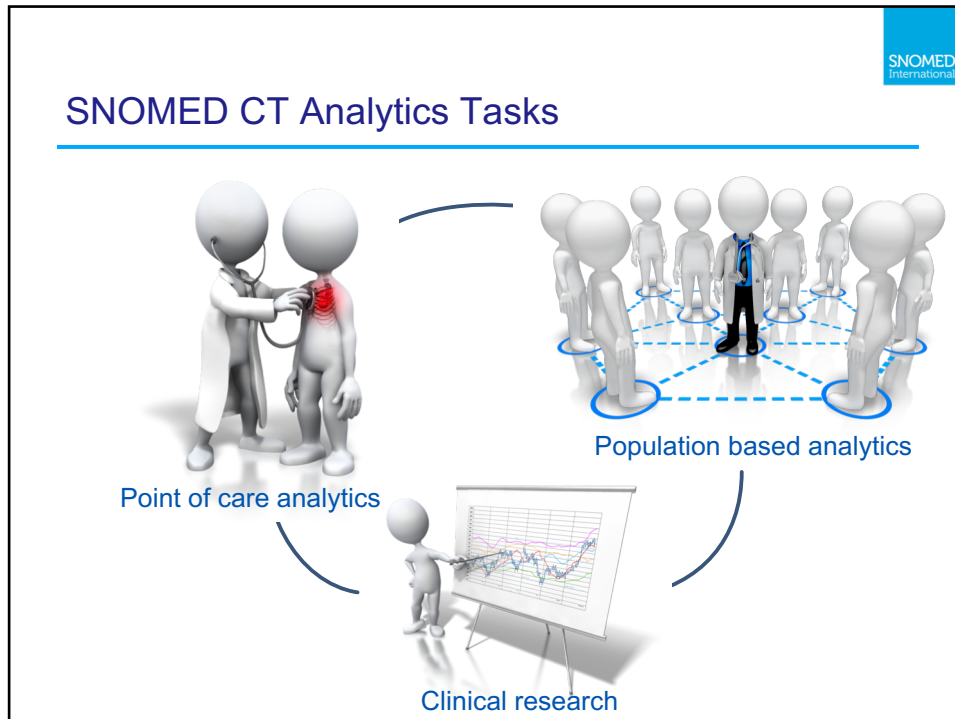
- SNOMED CT semantics are based on Description Logic
- This enables
 - The automation of reasoning across SNOMED CT
 - The implementation of more powerful analytics operations
 - Testing subsumption between concepts and expressions
 - Inferring new defining relationships
 - Transitive properties and property chaining
 - Reasoning with concrete values and GCIs
- Technique
 - Combine stated axioms into OWL 2 ontology
 - 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>






Data Analytics Tasks






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

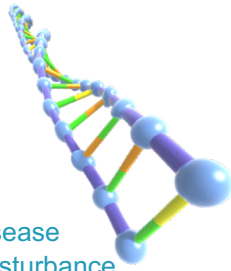
- **Trend analysis**
 - Extracting underlying patterns or trends in data
 - Detect change in incidence or prevalence of a disease, treatment, procedure or intervention over time
 - Used for population health monitoring, predication of demand, and effective resource allocation
- **Pharmacovigilance**
 - 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?


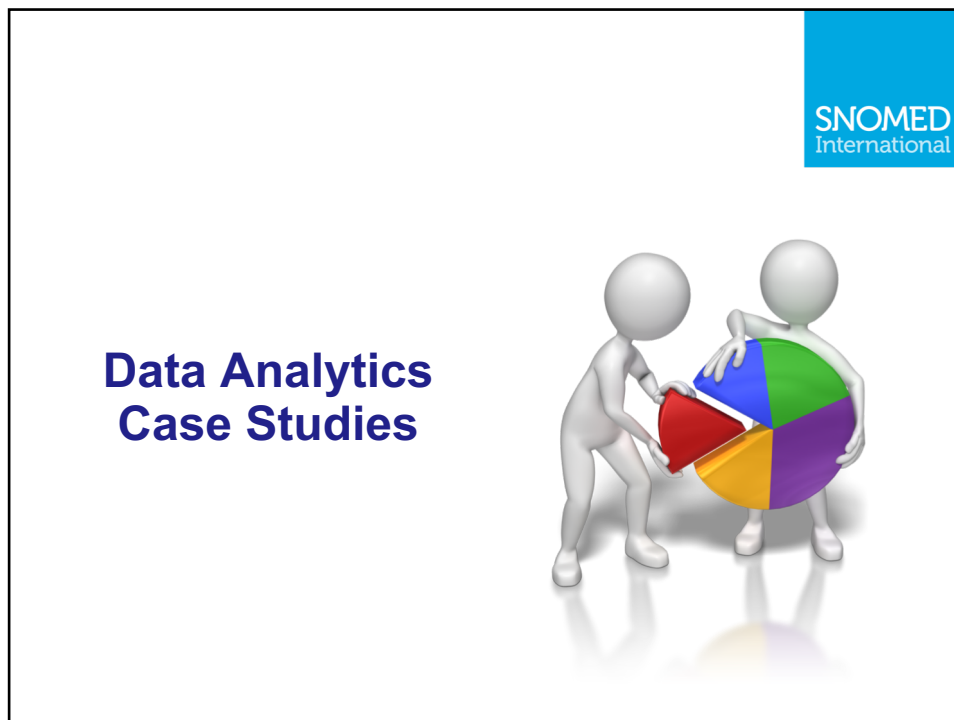




Clinical Research

- **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





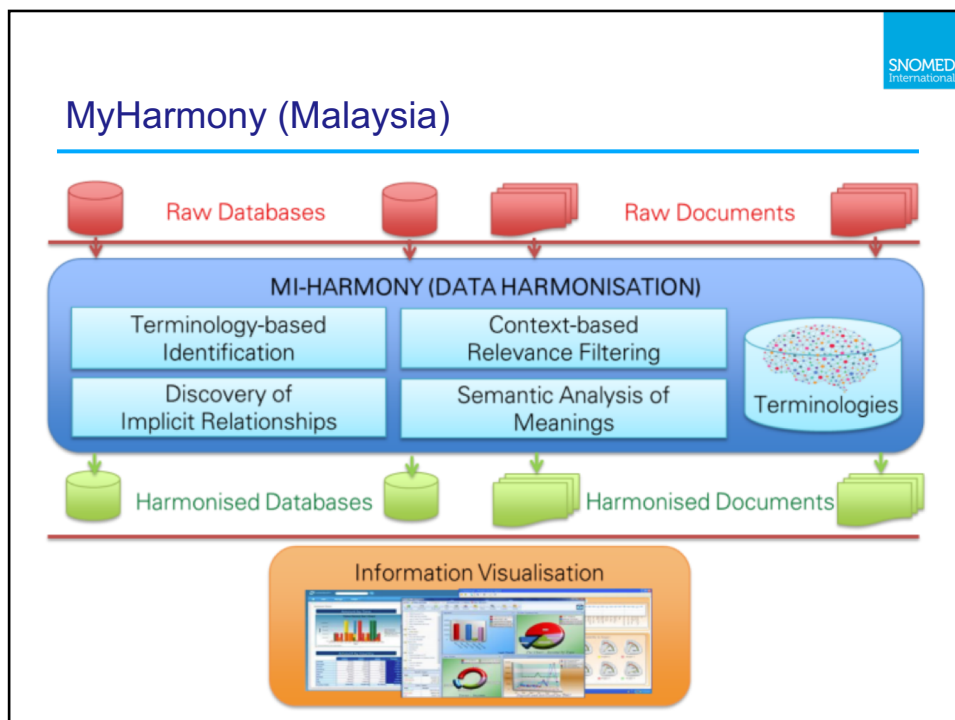
Kaiser Permanente (USA)

- 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

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MyHarmony (Malaysia)

- Application developed by Ministry of Health Malaysia and MIMOS
- Integrated into Malaysian Health Data Warehouse (MyHDW)
- Scope
 - Uses NLP to codify unstructured data with SNOMED CT
 - Cardiology discharge summary data, dental procedures (under dev), drug and traditional Chinese medicine (planned)
 - Generates cardiology Key Performance Indicators (KPIs)
- Why SNOMED CT
 - Comprehensive domain coverage and international standard
 - Enables wider range of analysis of healthcare data
 - More information can be generated from free-text
 - Reduces effort needed to collect structured data
 - New information can be generated by retrospectively running new queries on old records
 - Information can be delivered more quickly
 - Enables clinicians and health managers to plan and take action without waiting for yearly report



OHDSI (global)

- **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>



Semantic Search Tool

- Searching clinical knowledge bases using SNOMED CT

Miller, Christi... Age: 67 years Sex: Female Location: BW100; 10502; 01 Allergies: morphine, Penicillin

Miller, Christine Elizabeth Results: Not Subscribed Code Status: Full Resuscitation

Chart Search

Everything diabetes

Documents

Results

Results	Filter this search:
1.2 years ago High A1c 7.9 % High 4.0 - 6.0 Interpretation ...	
1.2 years ago Estimated Average Glucose 180 mg/dL High 65 - 109	
1.9 years ago Blood Glucose, Capillary 112 mg/dL	
2.5 years ago Blood Glucose, Capillary 123 mg/dL	
2.5 years ago Glucose, Random 120 mg/dL High 65 - 110	
2.5 years ago Estimated Average Glucose 148 mg/dL High 65 - 109	
2.5 years ago High A1c 6.8 % High 4.0 - 6.0 Interpretation ...	
2.7 years ago Glucose, Random 119 mg/dL High 65 - 110	

Office/Clinic Note-Physician: "Follow up hospitalization for diabetes." Hanson MD, Breana

Chief Complaint Diabetes check Interval History Diabetes, Type 2 Glucose results elevated, average 160 mg/dL and higher in the evening ... Type 2 diabetes mellitus / SNOMED CT 197761014 / Confirmed ... Type 2 diabetes mellitus (197761014): Onset in 1981 at 36 years.

2.7 years ago May 22, 2010 12:00 PM CDT Baseline West Medical Center

Admission Note-Physician: "Heart Failure." Swickie MD, Phyllis

metformin (metformin 500 mg oral tablet), 500 mg, 1 tab(s), PO, BID, 60 tab(s) Confirmed. Active Problems (5) Angina (299755016) At risk of pressure sore (4240) Type 2 diabetes mellitus (197761014)

Cerner Corporation









Why Clinical Decision Support is Valuable

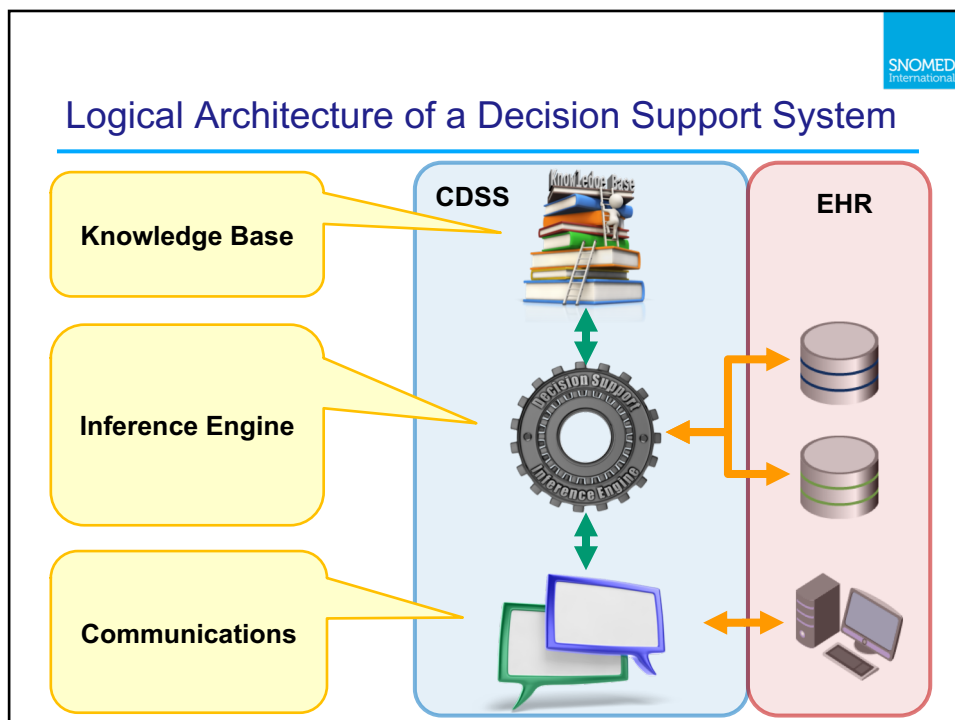
- It can help clinicians to make good decisions
 - Earlier accurate diagnosis
 - More appropriate treatment and follow up
 - Better health outcomes
- Raising quality of care for patients and the community
 - Reducing wasteful use of resources
 - Avoiding unnecessary investigations and treatment
- Decisions that contribute to
 - Improvements in the quality of life for patients
 - Professional satisfaction of health care professional
- Effective decision support requires
 - Clinical analytics underpinned by consistent recording of clinical information
 - ... which is where SNOMED CT fits in!

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Types of Clinical Decision Support


-  Alerts
-  Clinical guidelines / reference information
-  Conditional order sets / pathway support
-  Diagnostic support tools
-  Automated reports or smart forms
-  Retrospective review decision support



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Knowledge Base

Reference material, results of research and evidence-based rules derived from those resources

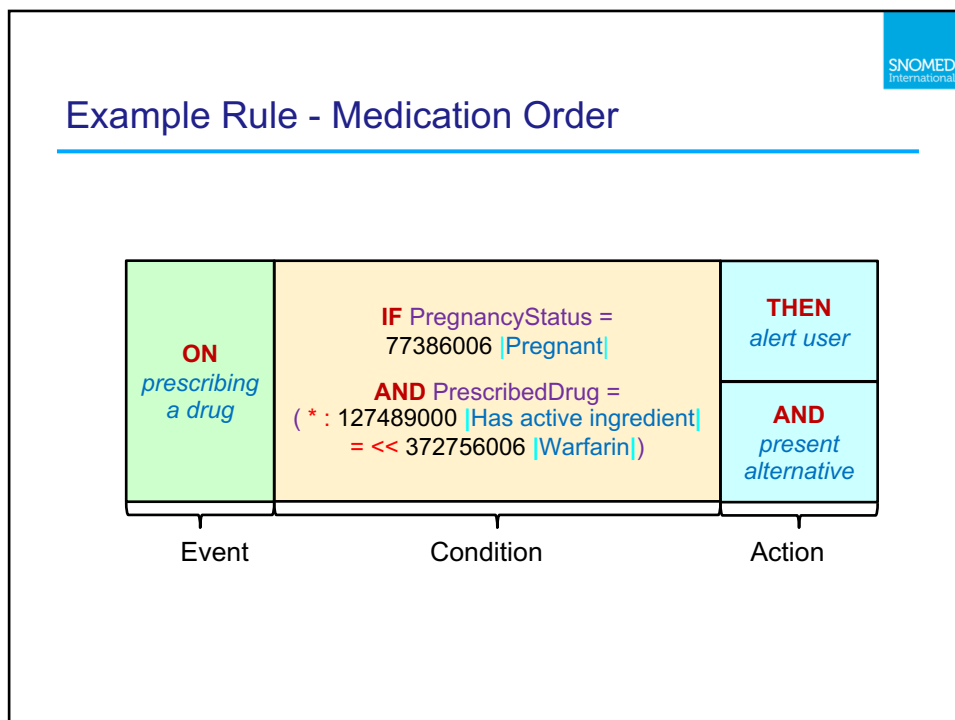
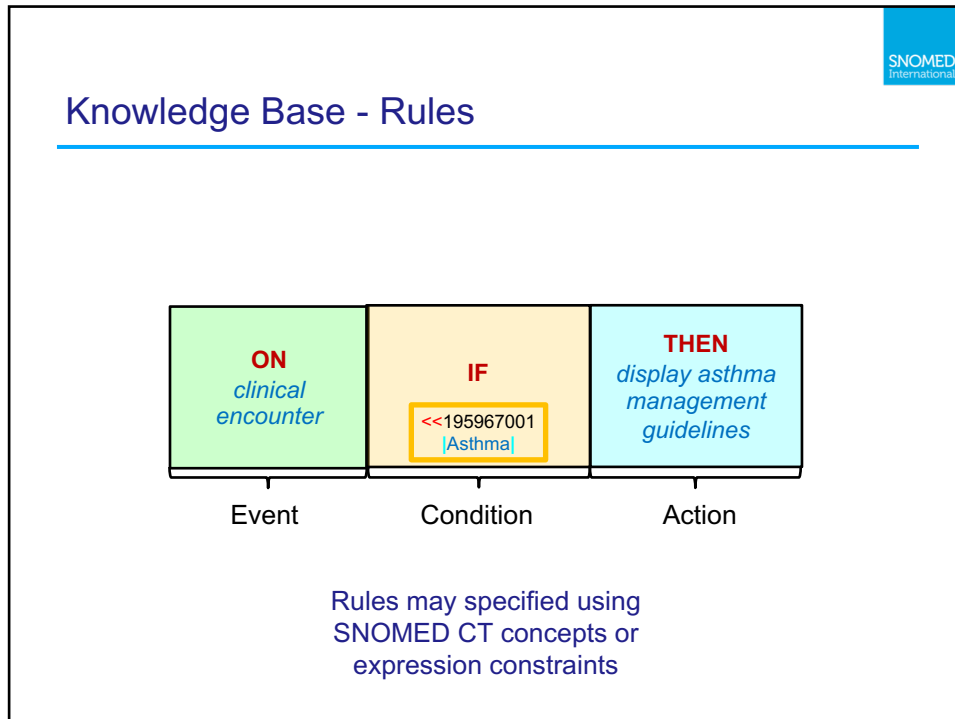


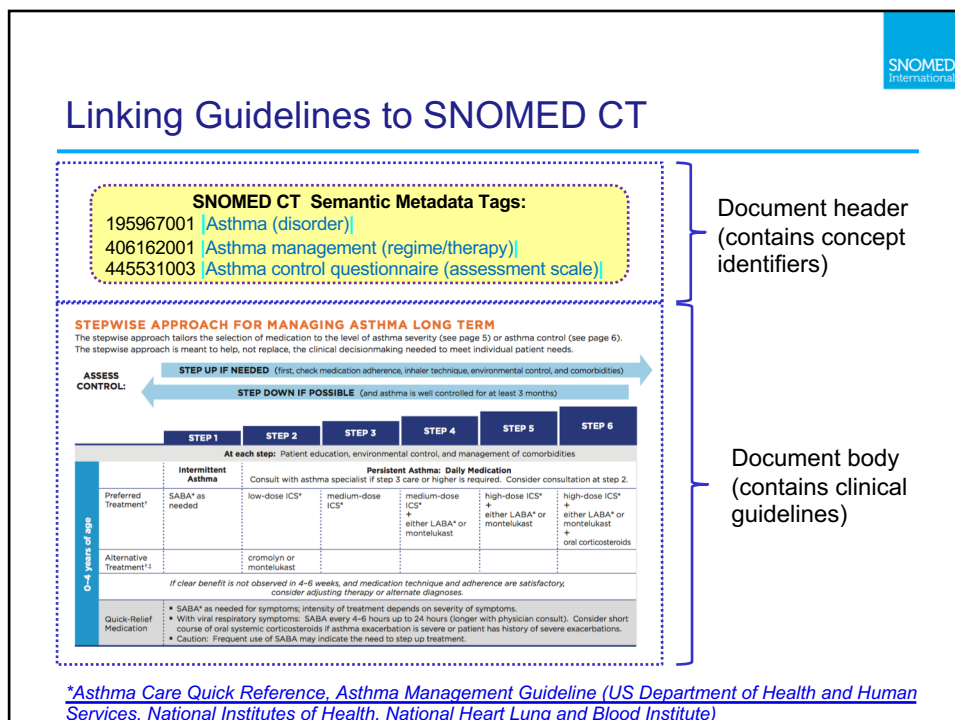
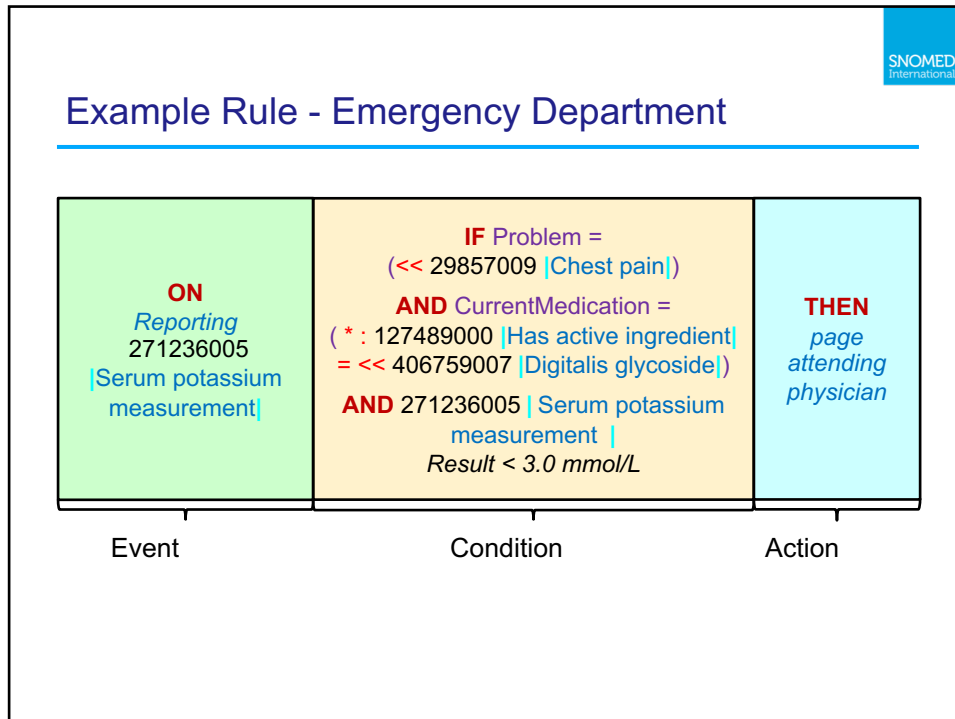
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Knowledge Base - Rules

ON <i>event</i>	IF <i>condition</i>	THEN <i>action</i>
Event	Condition	Action

Rules may specified using SNOMED CT concepts or expression constraints





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Selecting Relevant Guidelines

IF diagnosis = <<< 105967001 |Asthma|
THEN display NIH: Asthma Care Quick Reference

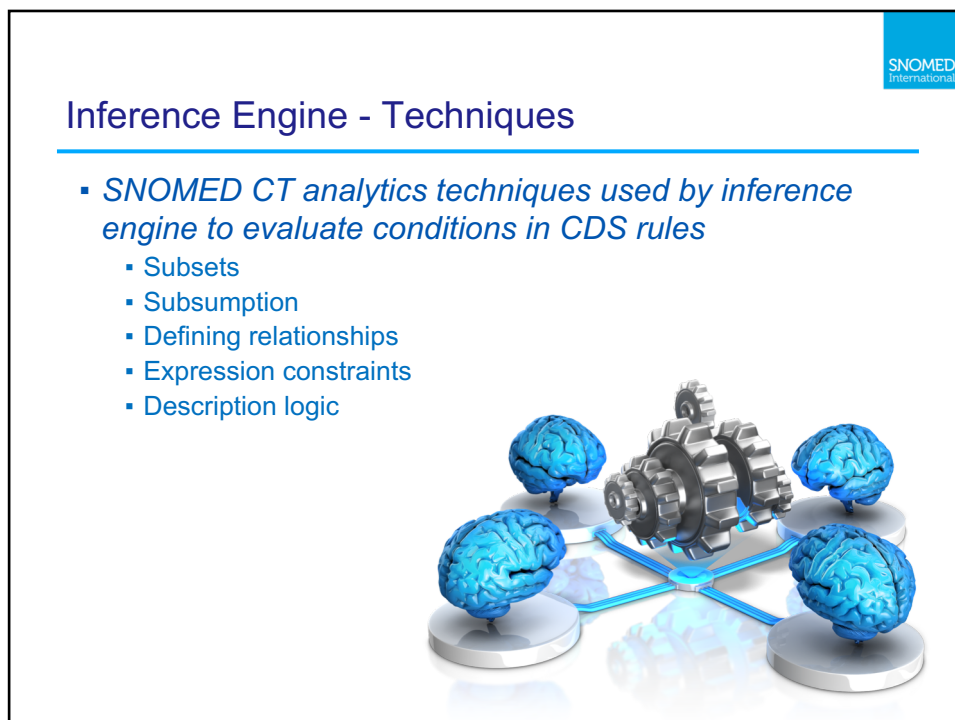
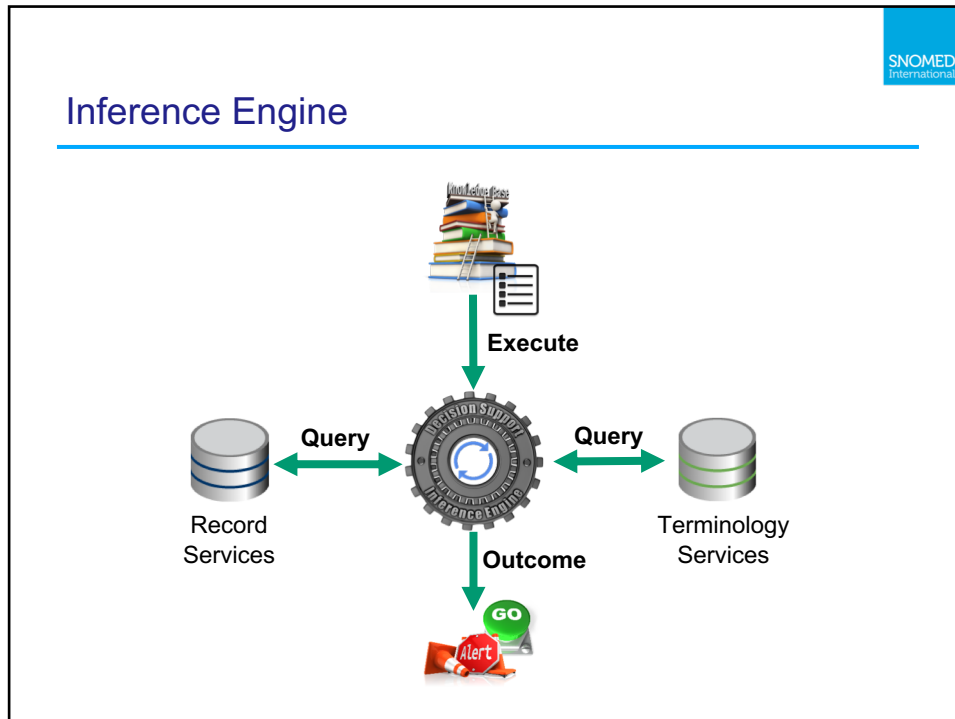
The diagram illustrates the process of selecting relevant guidelines. On the left, a 'Patient Encounter' window shows a 'Diagnosis' dropdown menu with 'Chronic asthmatic bronchitis' selected. Below it, a 'Knowledge Links' section displays 'NIH: Asthma Care Quick Reference'. A blue arrow points from the diagnosis dropdown to the knowledge link. On the right, a computer monitor displays a 'Semantic Link: 105967001 |Asthma|' highlighted in yellow. A purple arrow points from the monitor to the 'NIH: Asthma Care Quick Reference' link in the patient encounter window.

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Inference Engine

Applying knowledge base rules to health record data and user input

A large gear is shown with the text 'Decision Support' on the top half and 'Inference Engine' on the bottom half.



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CDS Example – Penicillin Allergy Alert

Patient: **Smith, John**

ALERT: Patient is allergic to penicillin.
[Search](#) for safe alternatives.

Clinical Notes

Allergies

- Penicillin

Medications:

- Amoxicillin 400mg tablet
- Amoxicillin 500mg tablet
- Amoxicillin 875mg tablet

Condition: Patient has penicillin allergy and clinician is prescribing new drug containing penicillin

Action: Display alert to clinicians

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CDS Example – Penicillin Allergy Alert

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

374646004
Amoxicillin 500 mg oral tablet

350162003
Product containing amoxicillin in oral dosage form (medicinal product form)

762949000
Has precise active ingredient (attribute)

372687004
Amoxicillin (substance)

Penicillin (substance)

- Substance with penicillin structure and antibacterial mechanism of action (substance)
- Broad spectrum penicillins (substance)
- Aminopenicillin (substance)
- Amoxicillin (substance)

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Inference Engine - Example

IF Procedure = (* :
 << 363704007 |Procedure site| =
 << 20139000 |Structure of respiratory system|)

THEN
 consult respirologist

Procedure:

Intermittent CPAP

Concept ID:
229308003

* : << 363704007 |Procedure site|
 = << 20139000
 |Structure of respiratory system|

SNOMED CT Inferred Relationships Table:

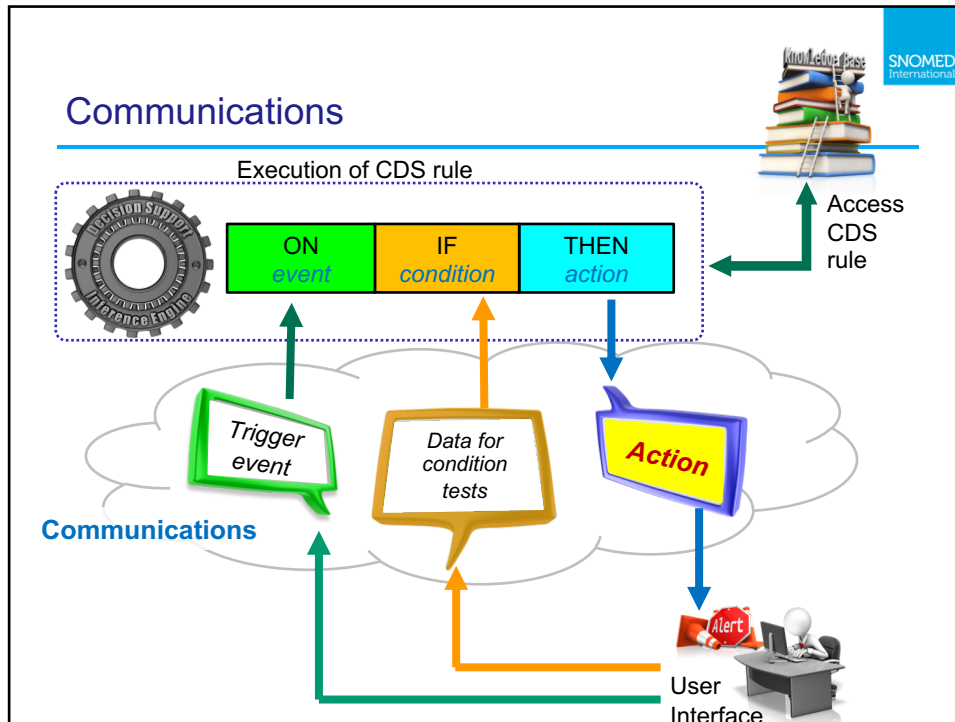
sourceId	destinationId	typeId
229308003	128258000	363702006
229308003	302803009	363702006
229308003	262202000	363703001
229308003	20139000	363704007
229308003	20139000	405813007
229308003	47545007	116680003
229308003	20139000	363704007

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

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Communication

Receiving data from user input and health records and responding with relevant information and guidance



Patient lists Sophia Patient

Sophia Patient PRN: PS452226 45 yrs F Patient Portal: Enrolled DOB: 06/11/1971 M: (666) 123-4567

Refresh to update clinical decision support (CDS) notifications below.

✓ Pompe Disease: This patient has clinical markers that are considered at risk for Pompe Disease. Consider ordering a GAA enzyme activity assay to confirm the absence or presence of diagnosis.

Citation: The Physician's Guide to Pompe Disease (Glycogen Storage Disease, Type II; Acid Maltase Deficiency). National Organization for Rare Disorders®, Danbury, CT. Arnold J.J. Reuser, Ph.D., Intervention Developer: Practice Fusion, Inc. Funding Source: Sanofi Genzyme Release Version: 1 Reference Information

Encounter details

ENCOUNTER TYPE: Office Visit NOTE TYPE: SOAP Note DATE: 7/7/2016

CHIEF COMPLAINT: Record No chief complaint recorded.

Flowsheets Edit US Customary Show

Vitals Add column Last 5 encounters or labs

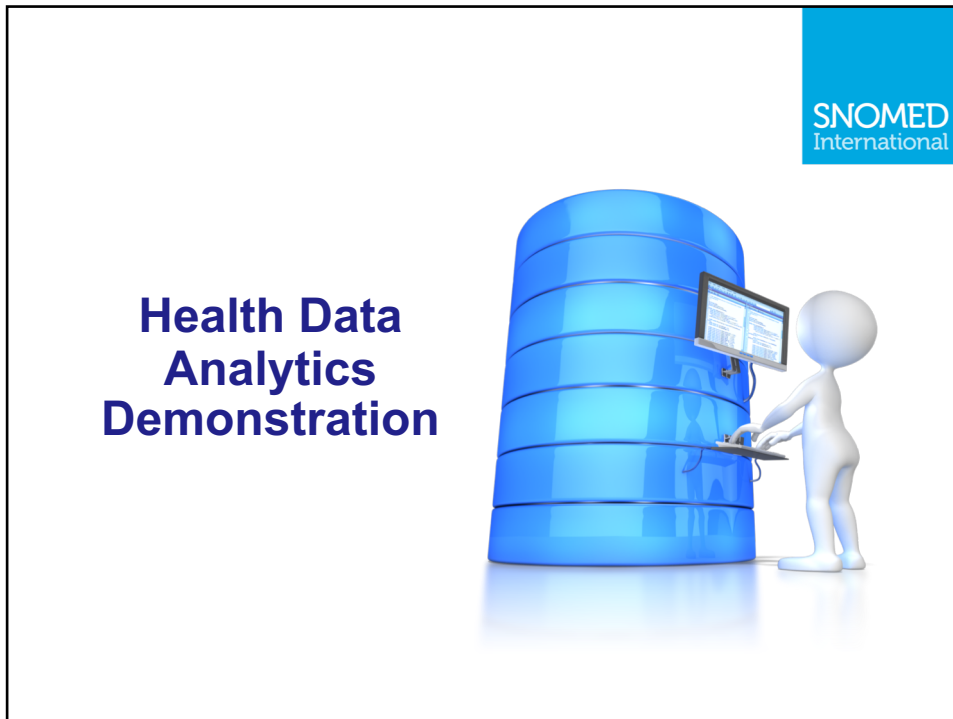
Vitals

Height Weight BMI BMI Percentile

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.](https://rarediseases.org/physician-guide/pompe-disease/#npq-symptoms)

Screen shot provided by Practice Fusion

<https://rarediseases.org/physician-guide/pompe-disease/#npq-symptoms>



Health Data Analytics

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- 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

3D illustrations of a doctor examining a patient's chest, and two pills (one white, one blue) are shown at the bottom.

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>

