A Probabilistic Look into the Semantics of Medicine

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Intermountain Healthcare

International Conference on
Semantic Computing 2014
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Agenda

- Medical Models
- "Big" Healthcare Data
  - Capture as a part of the care process
  - Strong Temporal Component
  - Inherently messy
- Extracting Models from Data
  - A place for Ontologies
  - Semi-Automatic extraction of Diagnostic Models
- Bayesian Modeling
  - Variations on the theme

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Models for Healthcare Delivery

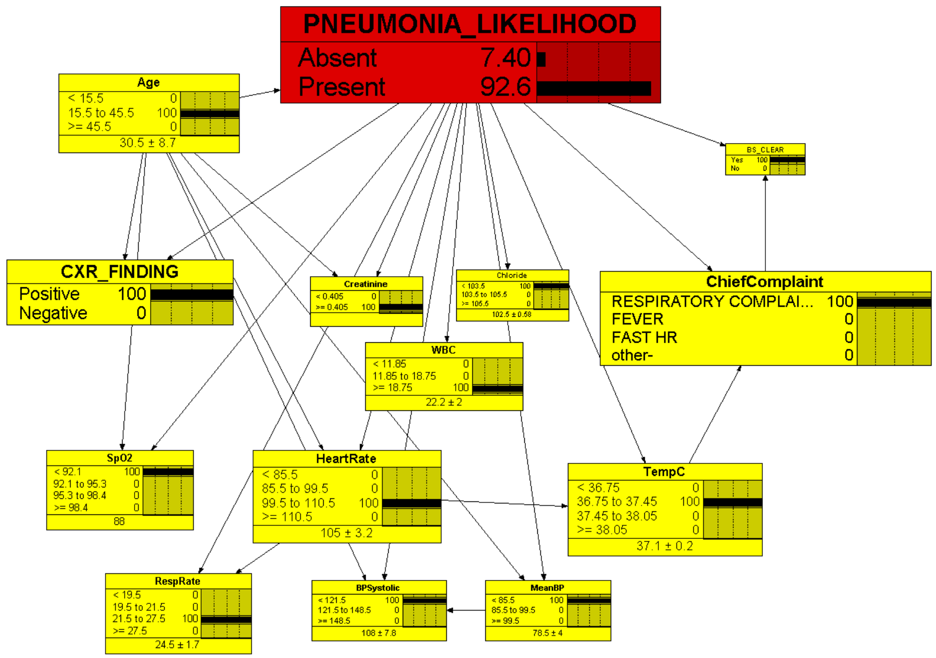
A foundation for clinical research and care delivery

Modeling and Model Implementation

- Medical Data Models
- Diagnostic Models
- Therapeutic Models
- Workflow/Business Process Models
- Clinical Trials Models
- Natural Language Models
- Research Models
- Physiologic Models
- Ontologies
- Temporal Models
- Predictive Models

Translational Research

Data Visualization



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Bayes Equation

Probability of Disease
When Finding exists

Probability of Both
The Disease and Finding

$$P(D \mid F) = \frac{P(F \text{ and } D)}{P(F)}$$

Probability of
Finding

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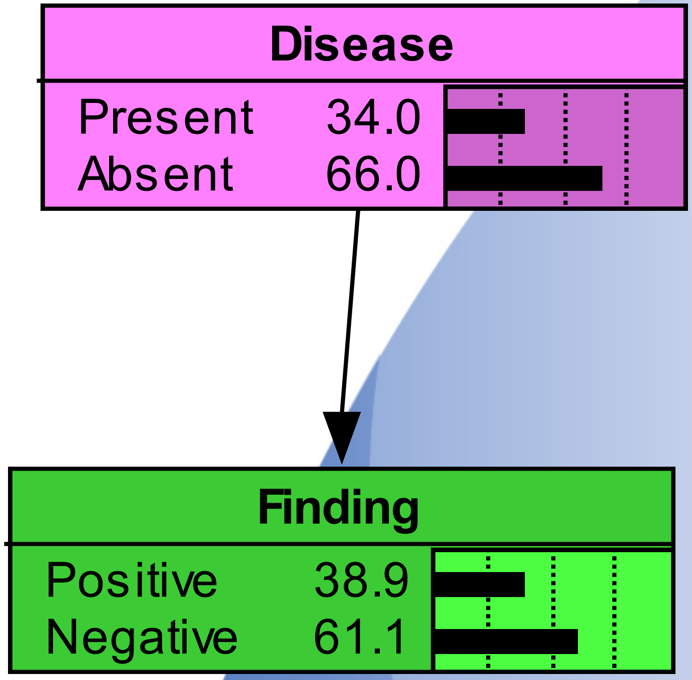
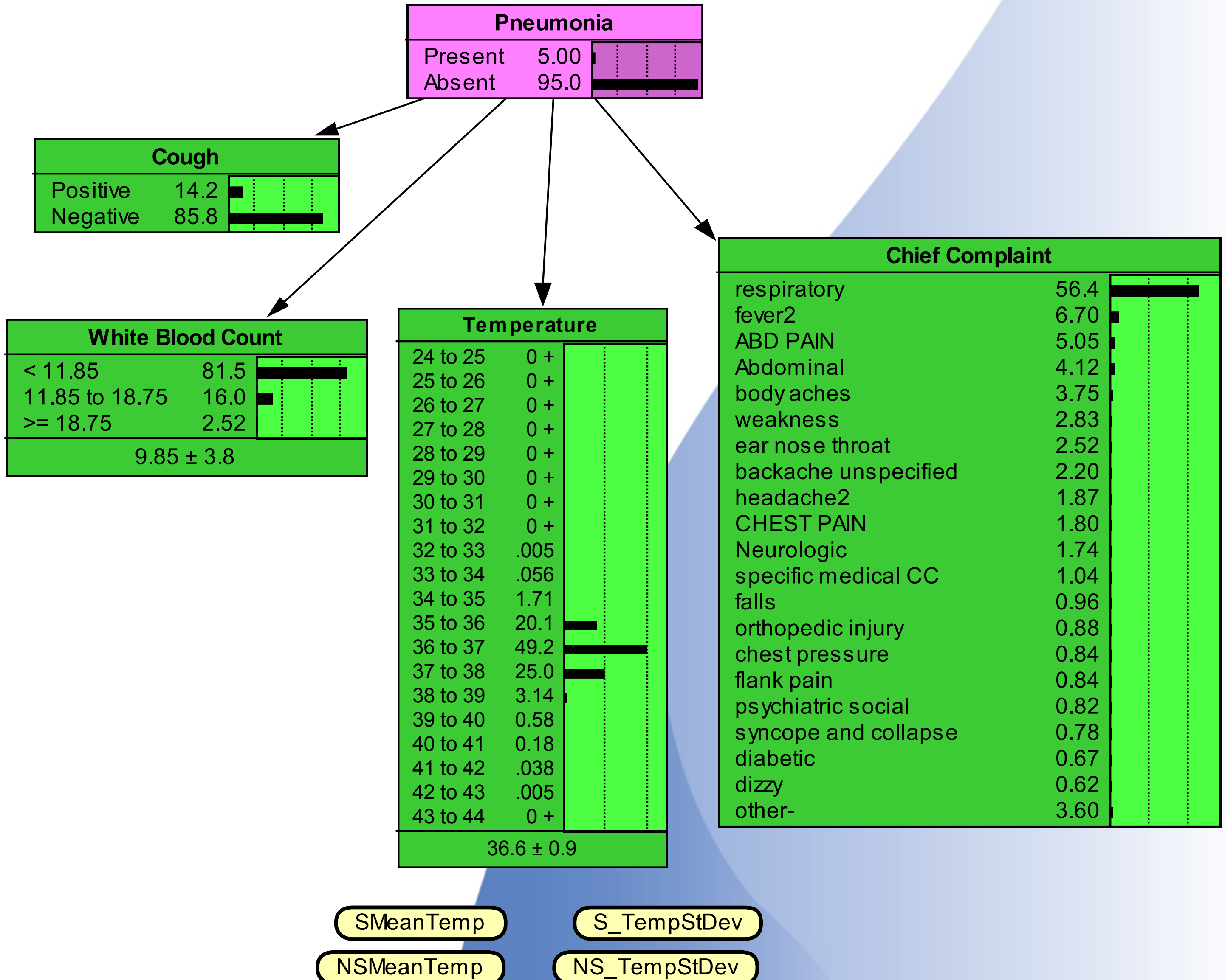
Bayes Equation-A Graphical View



Rendered as a Bayesian Network

Bayes Equation – Various Variables

Rendered as a Bayesian Network



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Sources for Building Medical Models

What are the sources of knowledge for Clinical Decision Support

- Clinical Trials
  - Prospective Trials
  - Observational Studies
- Physiologic Principals/Models
- Expert Opinion
- Common Sense
- CLINICAL DATA

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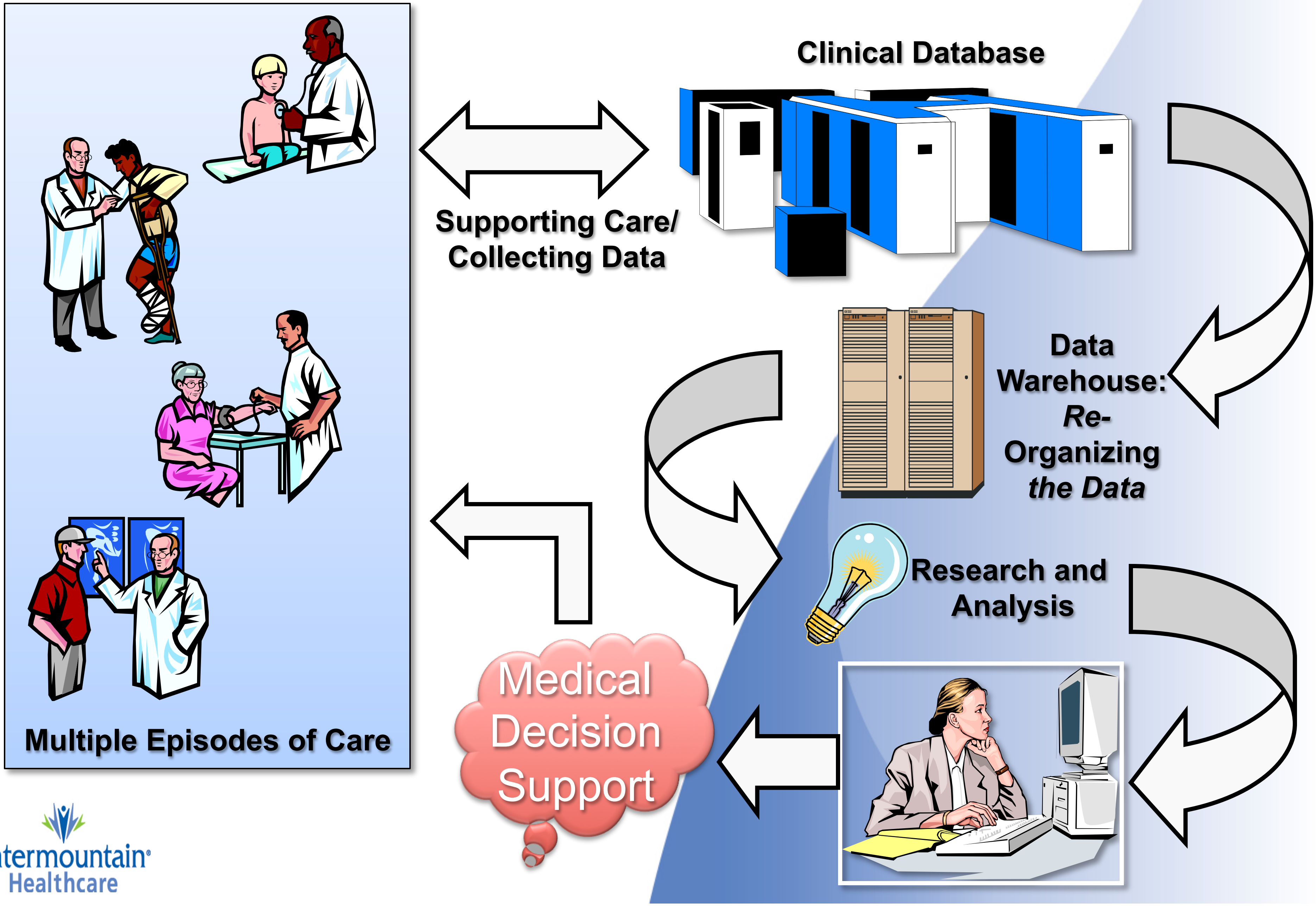
Clinical Data Serves Us Twice



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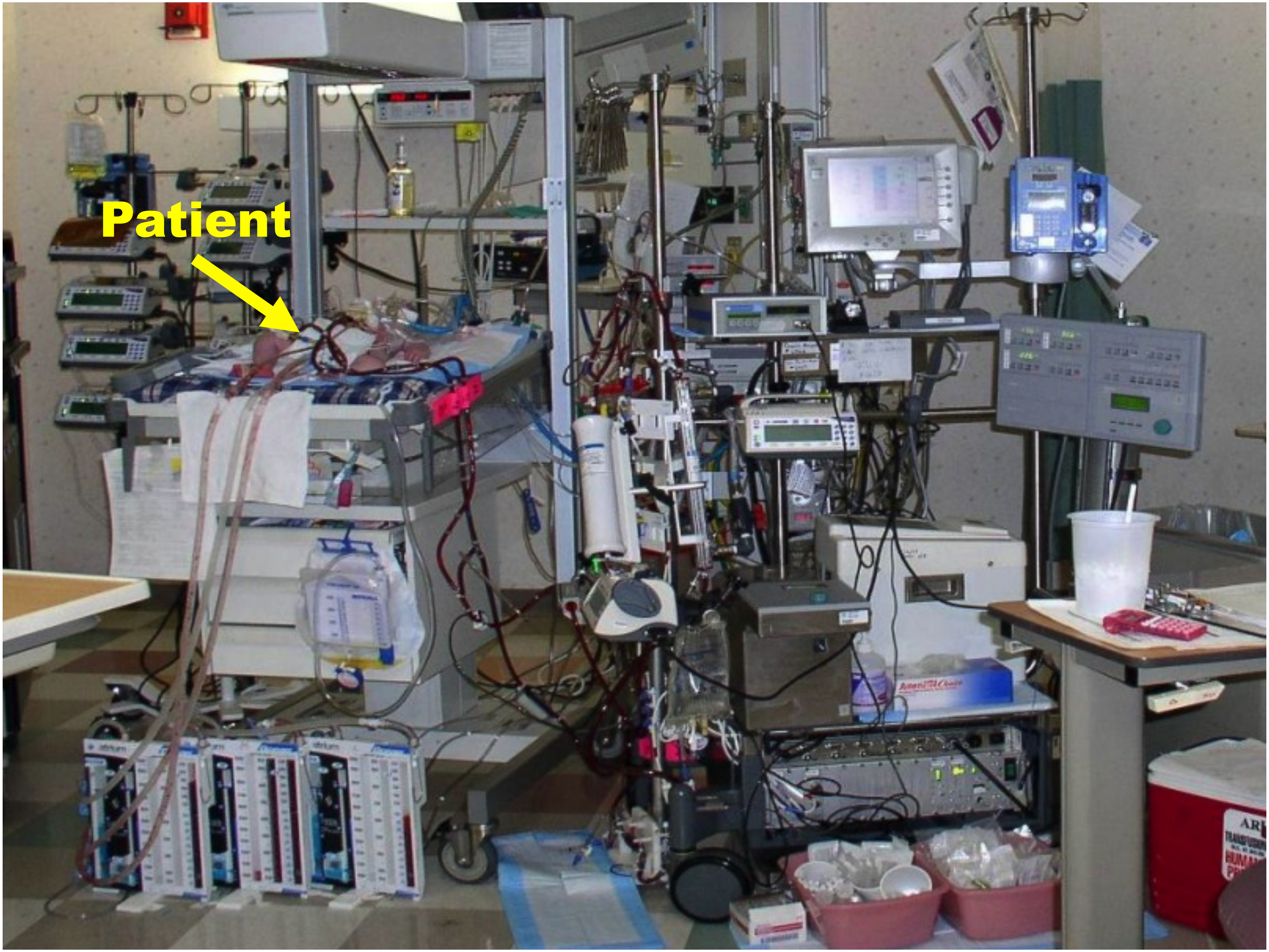
EDW Interesting Facts…

Fact	*Measure*
# of EDW login accounts	2500
# of EDW "Consumers"	Thousands
# Records in EDW	70,000,000,000
Size (bytes)	~ 10 Terabytes (production)
Avg monthly queries	~ 150,000,000
Most queried table	LKUP.PATIENT_MASTER
Largest table (records)	HELP.PT_DATA (Patient Data Table from HELP1) 19.5 Billion Records
# queriable tables	12,500
Avg query run time	6 seconds
Avg rows returned per query	3500
# of years of data (for major data sets)	10 – 15 years (25+ for others)


Patient

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Using Ontologies to Extract Build Diagnostic Models

There is a need for predictive (diagnostic) models for care.

- Predictive models have value in clinical care environments
  - Have successfully deployed pneumonia and sepsis diagnostic models
- Building models from data is resource intensive.
- Ontologies can support diagnostic modeling
  - Requires a database containing data collected during routine care.
  - An **Ontology** to capture clinical relationships among data elements.
  - An application (the Ontology-driven Diagnostic Modeling System) is used to automate the initial analysis.

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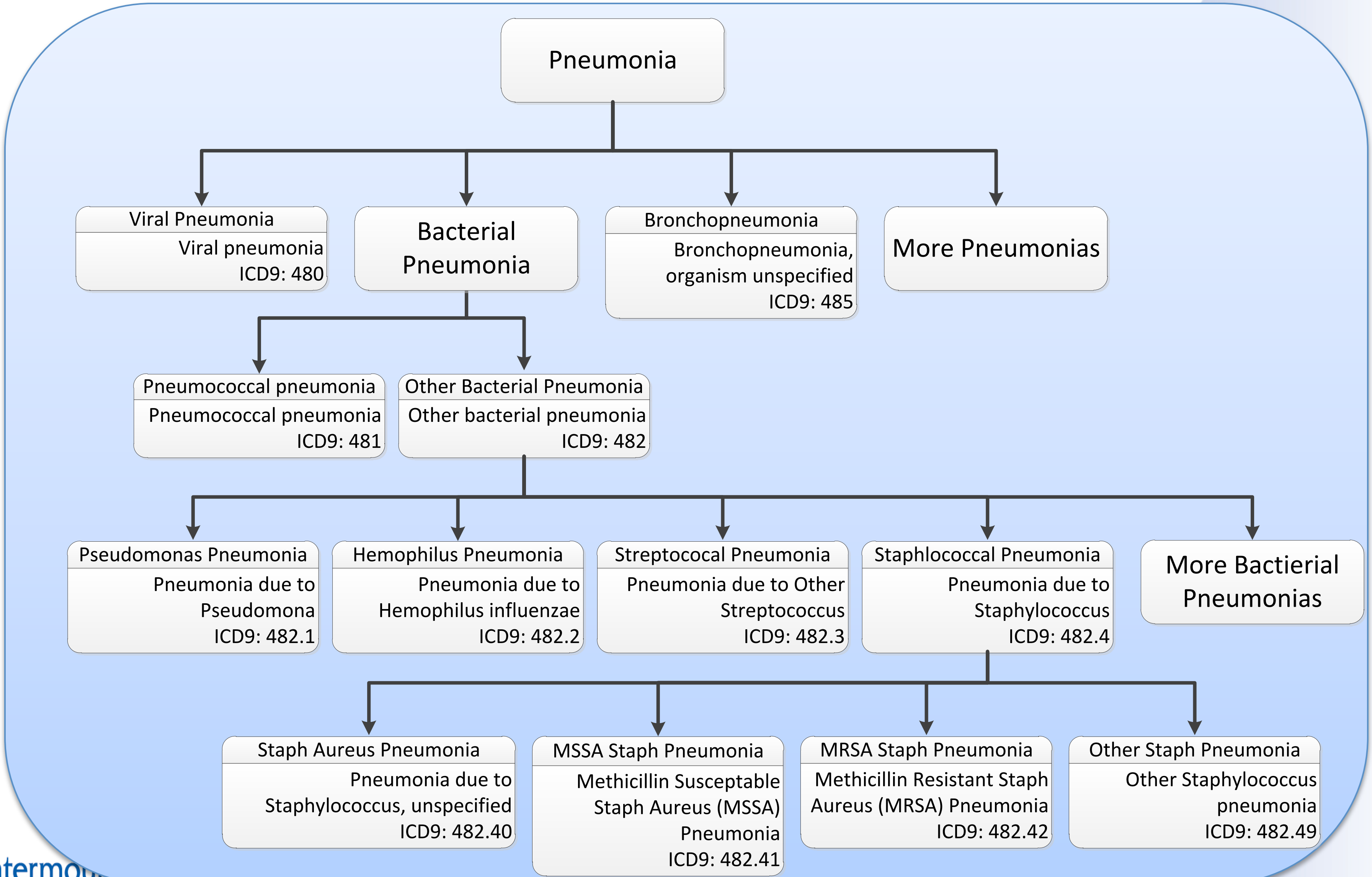
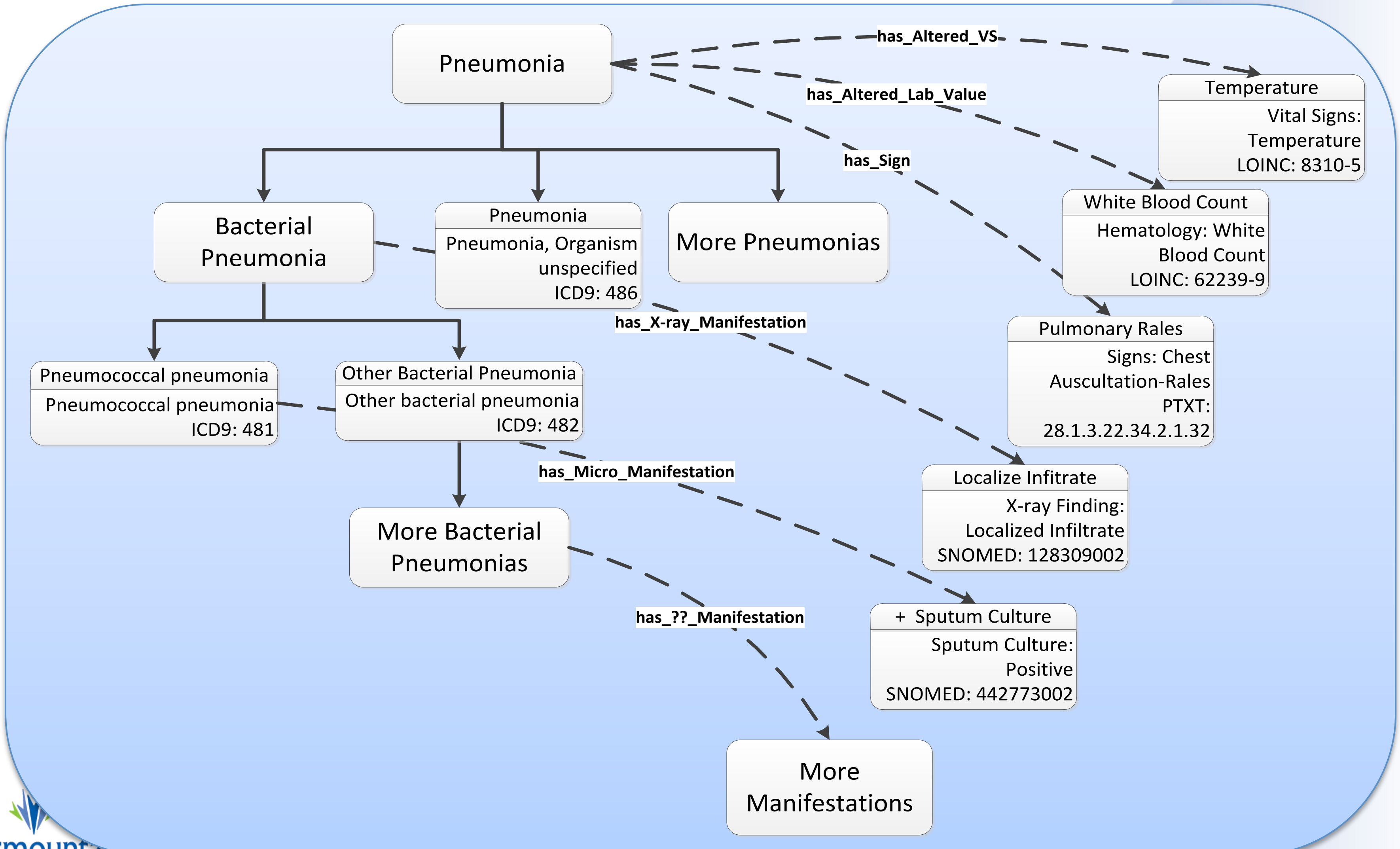
Ontologies Describe How Diseases Are Related
(according to ICD9)



Ontologies Describe How Clinical Data are Related to Diseases



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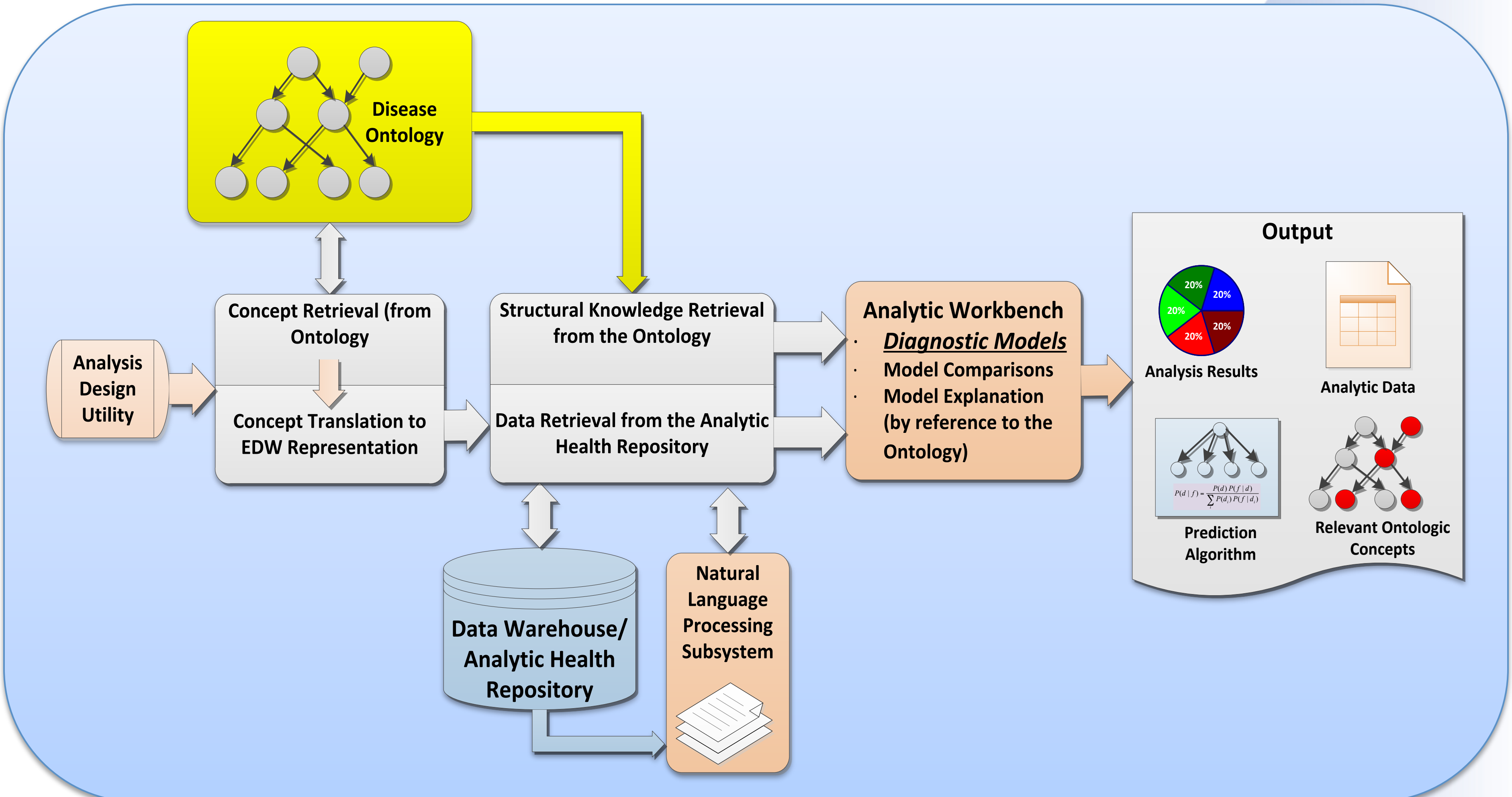
Ontology-Driven Model Discovery

Using knowledge embedded in ontologies to automate research?



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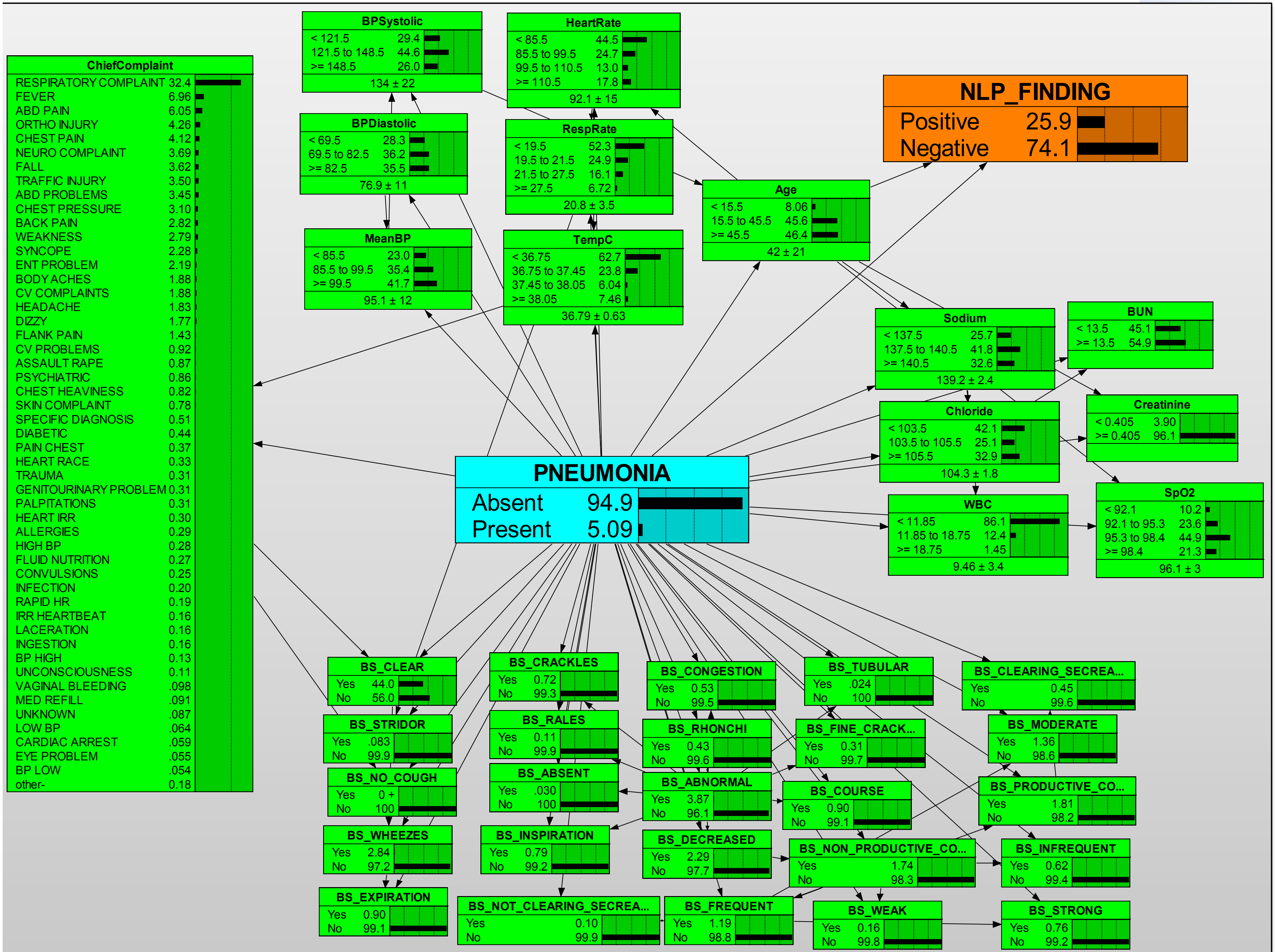
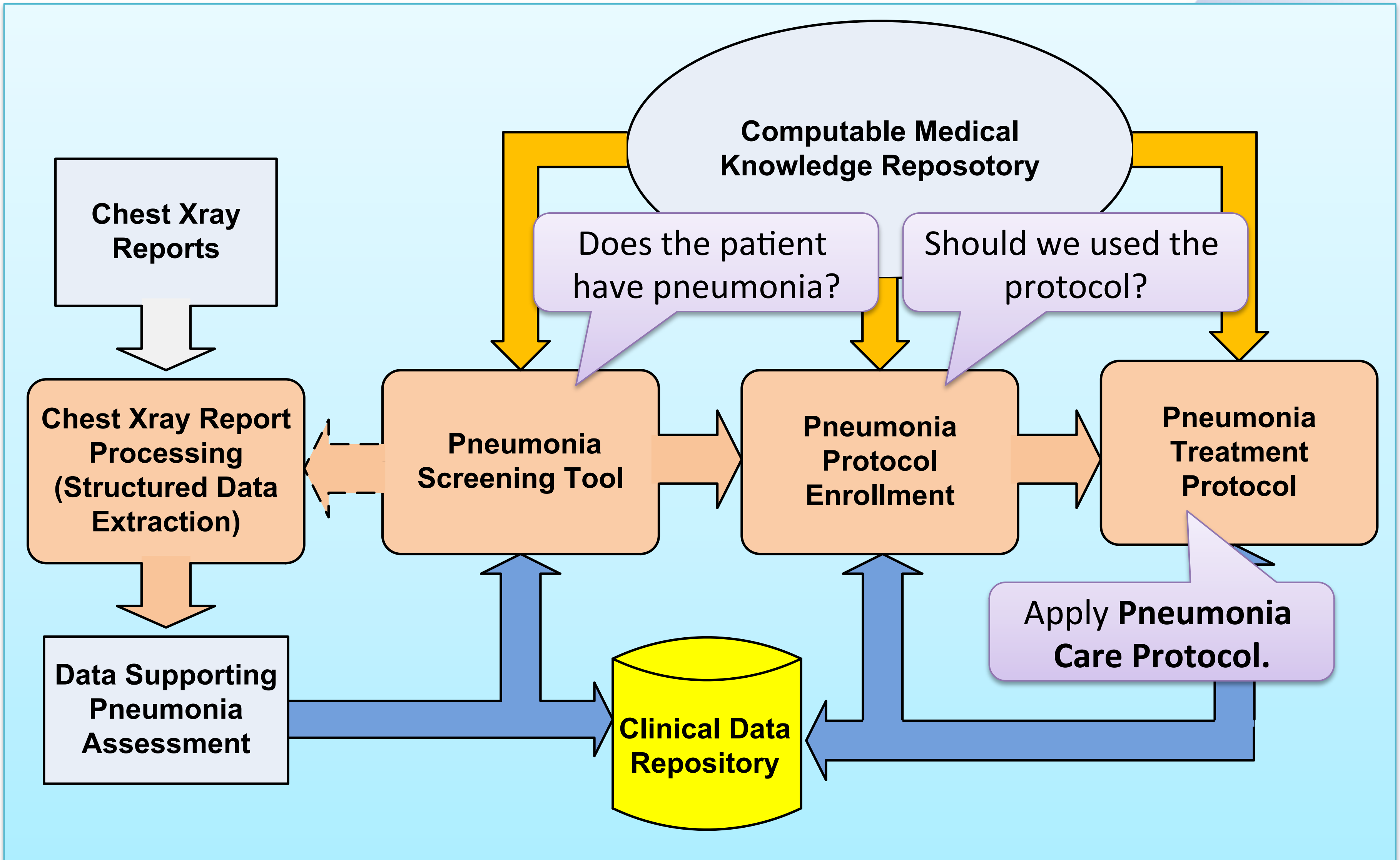


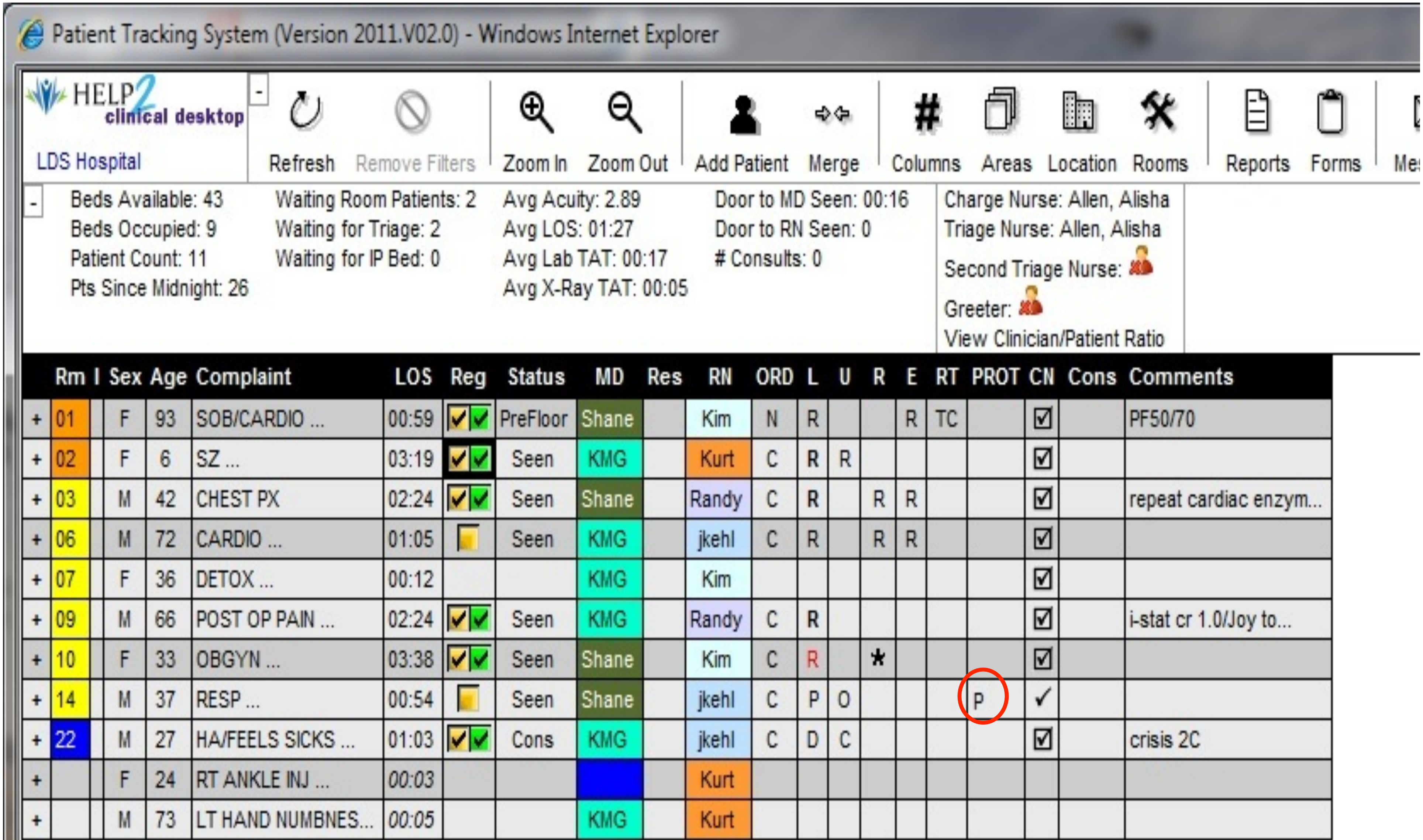
ChiefComplaint
RESPIRATORY COMPLAINT 32.4
FEVER 6.96
ABD PAIN 6.05
ORTHO INJURY 4.26
CHEST PAIN 4.12
NEURO COMPLAINT 3.69
FALL 3.62
TRAFFIC INJURY 3.50
ABD PROBLEMS 3.45
CHEST PRESSURE 3.10
BACK PAIN 2.82
WEAKNESS 2.79
SYNCOPE 2.28
ENT PROBLEM 2.19
BODY ACHES 1.88
CV COMPLAINTS 1.88
HEADACHE 1.83
DIZZY 1.77
FLANK PAIN 1.43
CV PROBLEMS 0.92
ASSAULT RAPE 0.87
PSYCHIATRIC 0.86
CHEST HEAVINESS 0.82
SKIN COMPLAINT 0.78
SPECIFIC DIAGNOSIS 0.51
DIABETIC 0.44
PAIN CHEST 0.37
HEART RACE 0.33
TRAUMA 0.31
GENITOURINARY PROBLEM 0.31
PALPITATIONS 0.31
HEART IRR 0.30
ALLERGIES 0.29
HIGH BP 0.28
FLUID NUTRITION 0.27
CONVULSIONS 0.25
INFECTION 0.20
RAPID HR 0.19
IRR HEARTBEAT 0.16
LACERATION 0.16
INGESTION 0.16
BP HIGH 0.13
UNCONSCIOUSNESS 0.11
VAGINAL BLEEDING .098
MED REFILL .091
UNKNOWN .087
LOW BP .064
CARDIAC ARREST .059
EYE PROBLEM .055
BP LOW .054
other- 0.18
BPSystolic
< 121.5 29.4
121.5 to 148.5 44.6
>= 148.5 26.0
134 ± 22
HeartRate
< 85.5 44.5
85.5 to 99.5 24.7
99.5 to 110.5 13.0
>= 110.5 17.8
92.1 ± 15
NLP_FINDING
Positive 25.9
Negative 74.1
BPDiastolic
< 69.5 28.3
69.5 to 82.5 36.2
>= 82.5 35.5
76.9 ± 11
RespRate
< 19.5 52.3
19.5 to 21.5 24.9
21.5 to 27.5 16.1
>= 27.5 6.72
20.8 ± 3.5
Age
< 15.5 8.06
15.5 to 45.5 45.6
>= 45.5 46.4
42 ± 21
MeanBP
< 85.5 23.0
85.5 to 99.5 35.4
>= 99.5 41.7
95.1 ± 12
TempC
< 36.75 62.7
36.75 to 37.45 23.8
37.45 to 38.05 6.04
>= 38.05 7.46
36.79 ± 0.63
Sodium
< 137.5 25.7
137.5 to 140.5 41.8
>= 140.5 32.6
139.2 ± 2.4
BUN
< 13.5 45.1
>= 13.5 54.9
Chloride
< 103.5 42.1
103.5 to 105.5 25.1
>= 105.5 32.9
104.3 ± 1.8
Creatinine
< 0.405 3.90
>= 0.405 96.1
PNEUMONIA
Absent 94.9
Present 5.09
WBC
< 11.85 86.1
11.85 to 18.75 12.4
>= 18.75 1.45
9.46 ± 3.4
SpO2
< 92.1 10.2
92.1 to 95.3 23.6
95.3 to 98.4 44.9
>= 98.4 21.3
96.1 ± 3
BS_CLEAR
Yes 44.0
No 56.0
BS_CRACKLES
Yes 0.72
No 99.3
BS_CONGESTION
Yes 0.53
No 99.5
BS_TUBULAR
Yes .024
No 100
BS_CLEARING_SECREA...
Yes 0.45
No 99.6
BS_STRIDOR
Yes .083
No 99.9
BS_RALES
Yes 0.11
No 99.9
BS_RHONCHI
Yes 0.43
No 99.6
BS_FINE_CRACK...
Yes 0.31
No 99.7
BS_MODERATE
Yes 1.36
No 98.6
BS_NO_COUGH
Yes 0 +
No 100
BS_ABSENT
Yes .030
No 100
BS_ABNORMAL
Yes 3.87
No 96.1
BS_COURSE
Yes 0.90
No 99.1
BS_PRODUCTIVE_CO...
Yes 1.81
No 98.2
BS_WHEEZES
Yes 2.84
No 97.2
BS_INSPIRATION
Yes 0.79
No 99.2
BS_DECREASED
Yes 2.29
No 97.7
BS_NON_PRODUCTIVE_CO...
Yes 1.74
No 98.3
BS_INFREQUENT
Yes 0.62
No 99.4
BS_EXPIRATION
Yes 0.90
No 99.1
BS_NOT_CLEARING_SECREA...
Yes 0.10
No 99.9
BS_FREQUENT
Yes 1.19
No 98.8
BS_WEAK
Yes 0.16
No 99.8
BS_STRONG
Yes 0.76
No 99.2

A Care Delivery Framework

(multi-factor screening and treatment)

Example: Community-Acquired Pneumonia

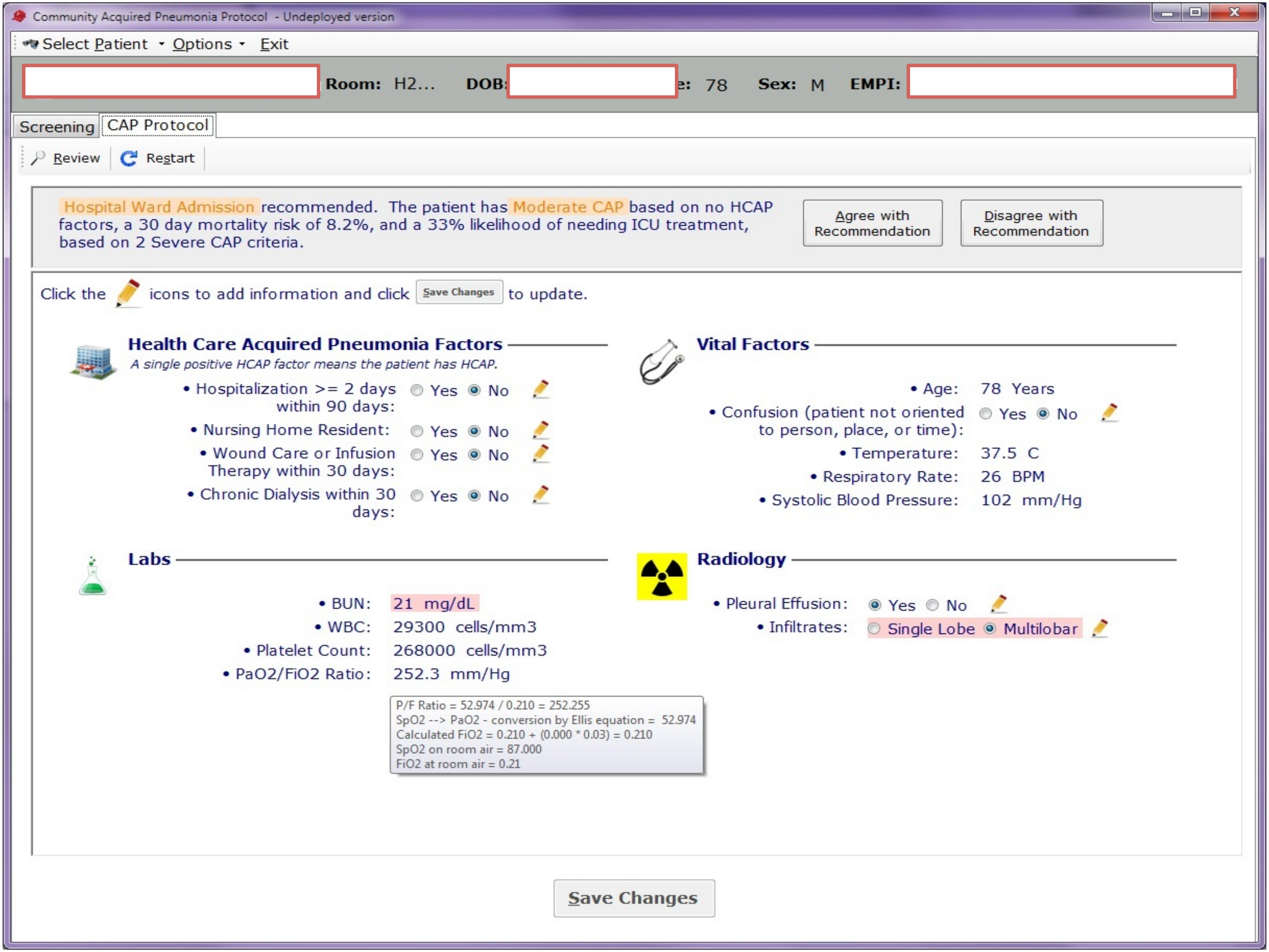




	Rm	I	Sex	Age	Complaint	LOS	Reg	Status	MD	Res	RN	ORD	L	U	R	E	RT	PROT	CN	Cons	Comments
+	01		F	93	SOB/CARDIO ...	00:59	✓✓	PreFloor	Shane		Kim	N	R			R	TC		☑		PF50/70
+	02		F	6	SZ ...	03:19	✓✓	Seen	KMG		Kurt	C	R	R					☑		
+	03		M	42	CHEST PX	02:24	✓✓	Seen	Shane		Randy	C	R		R	R			☑		repeat cardiac enzym...
+	06		M	72	CARDIO ...	01:05		Seen	KMG		jkehl	C	R		R	R			☑		
+	07		F	36	DETOX ...	00:12			KMG		Kim								☑		
+	09		M	66	POST OP PAIN ...	02:24	✓✓	Seen	KMG		Randy	C	R						☑		i-stat cr 1.0/Joy to...
+	10		F	33	OBGYN ...	03:38	✓✓	Seen	Shane		Kim	C	R		*				☑		
+	14		M	37	RESP ...	00:54		Seen	Shane		jkehl	C	P	O				P	✓		
+	22		M	27	HA/FEELS SICKS ...	01:03	✓✓	Cons	KMG		jkehl	C	D	C					☑		crisis 2C
+			F	24	RT ANKLE INJ ...	00:03					Kurt										
+			M	73	LT HAND NUMBNES...	00:05			KMG		Kurt										

Alerting for Pneumonia in the Patient Tracking System

- System Watches the Data Flow in the ED
- Identifies Possible Pneumonia Patients


Community Acquired Pneumonia Protocol - Undeployed version
Select Patient
Options
Exit
Room: H2...
DOB:
e: 78
Sex: M
EMPI:
Screening
CAP Protocol
Review
Restart
Hospital Ward Admission recommended. The patient has Moderate CAP based on no HCAP factors, a 30 day mortality risk of 8.2%, and a 33% likelihood of needing ICU treatment, based on 2 Severe CAP criteria.
Agree with Recommendation
Disagree with Recommendation
Click the icons to add information and click Save Changes to update.
Health Care Acquired Pneumonia Factors
A single positive HCAP factor means the patient has HCAP.
• Hospitalization >= 2 days within 90 days: Yes No
• Nursing Home Resident: Yes No
• Wound Care or Infusion Therapy within 30 days: Yes No
• Chronic Dialysis within 30 days: Yes No
Vital Factors
• Age: 78 Years
• Confusion (patient not oriented to person, place, or time): Yes No
• Temperature: 37.5 C
• Respiratory Rate: 26 BPM
• Systolic Blood Pressure: 102 mm/Hg
Labs
• BUN: 21 mg/dL
• WBC: 29300 cells/mm3
• Platelet Count: 268000 cells/mm3
• PaO2/FiO2 Ratio: 252.3 mm/Hg
P/F Ratio = 52.974 / 0.210 = 252.255
SpO2 --> PaO2 - conversion by Ellis equation = 52.974
Calculated FiO2 = 0.210 + (0.000 * 0.03) = 0.210
SpO2 on room air = 87.000
FiO2 at room air = 0.21
Radiology
• Pleural Effusion: Yes No
• Infiltrates: Single Lobe Multilobar
Save Changes

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- Extracting Models from Data
  - The classic research paradigm
  - Semi-Automatic extraction of Diagnostic Models
- **Bayesian Modeling**
  - **Variations on the theme**

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Intermountain Sepsis Bundle

To be successful, 11 components of the Sepsis Bundle should be accomplished.

IMCP Adult Severe Sepsis/Septic Shock Bundle Handoff/Checklist - 2014

Patient Name: ________________________ **ENC:** ____________ **Date of Admission:** _____/_____/_____

	:	← "Time Zero" (ED admits = time of arrival. -- Floor admits = time of admission to ICU or IMC)
	:	← Enter Patient's Height

Complete tasks within 3 or 1 hour from Time Zero			
	:	← Enter "Time Zero" + 3 hours for ED patients **or** + 1 hour for other inpatient unit arrivals	
		Severe Sepsis Resuscitation Bundle	
	Compliant?	**Goal: to be done within a max. of 3 hours from "Time Zero" above or for non-ED patients within 1 hour from "Time Zero" above**	
		1. Measure serum lactate. (if ≥ 2, see #7 below)	Time Drawn: ____:____
		2. Obtain blood cultures prior to antibiotic administration	Time Drawn: ____:____
		3. Broad-spectrum antibiotic administration*: (see below)	Time started: ____:____
		4. Fluid bolus of 30 ml/kg Predicted Body Weight (PBW) of crystalloid IV over 1 hour PRN MAP < 65 and/or Lactate ≥ 4 mmol/L **(See height to fluid bolus conversion table)**	

plete tasks within rs from Time Zero		
	:	← Enter the above **"Time Zero"** + 6 hours
		Septic Shock Bundle
	Compliant?	• **If persistent hypotension (MAP < 60) after fluid bolus proceed to step 5-6** • **If persistent hypotension (MAP < 60) after fluid bolus and/or most recent lactate ≥ 4, begin further volume resuscitation and vasopressor support as needed to achieve step 6**
		5. Administer Vasopressors (norepinephrine is preferred if not contraindicated)
		6. Place central monitoring line and measure CVP and ScvO2 **or** use NICOM for further fluid

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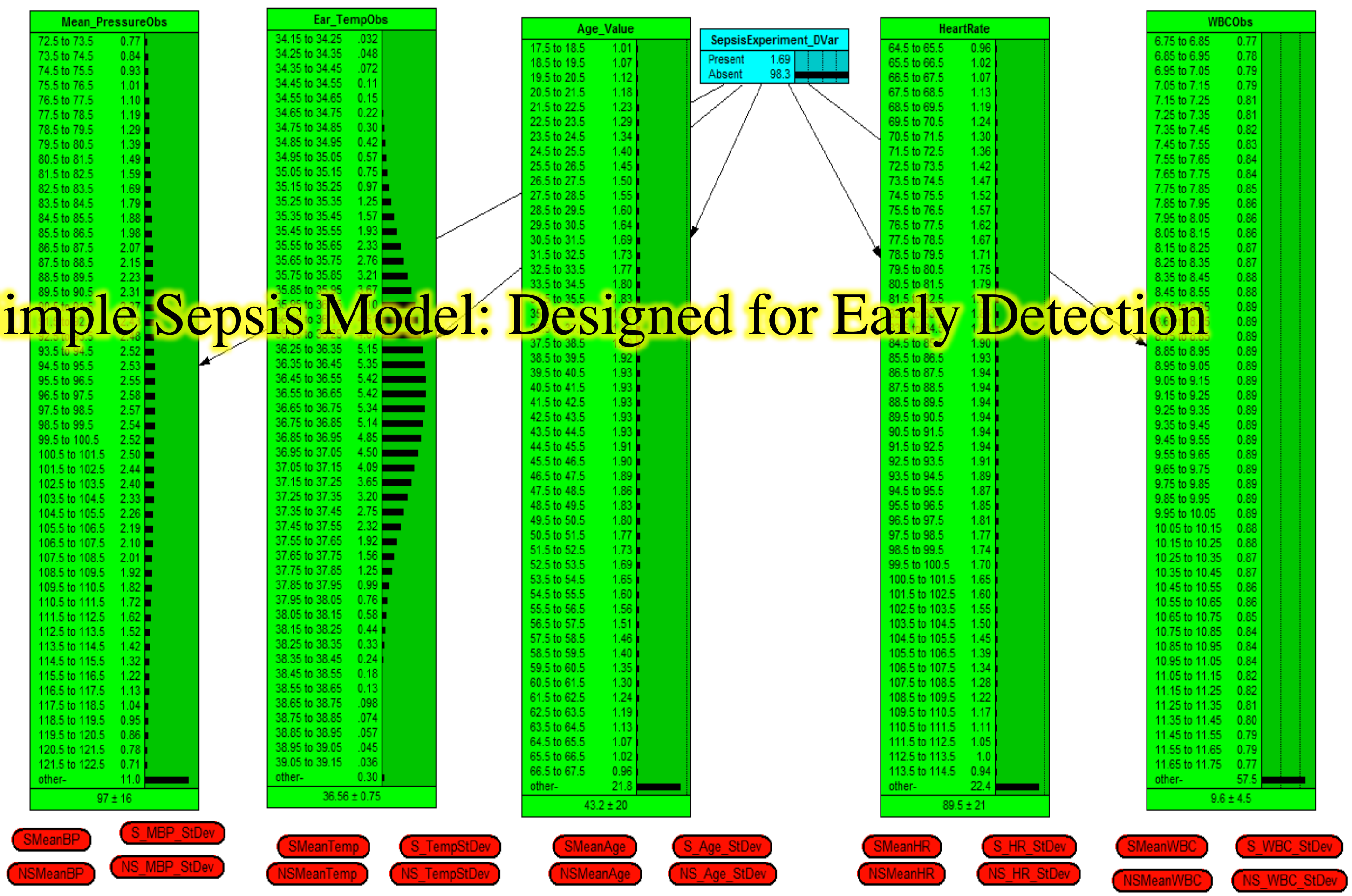
Screening Sepsis Model

Goal: Identify Sepsis Patients within 2 hours of admission.



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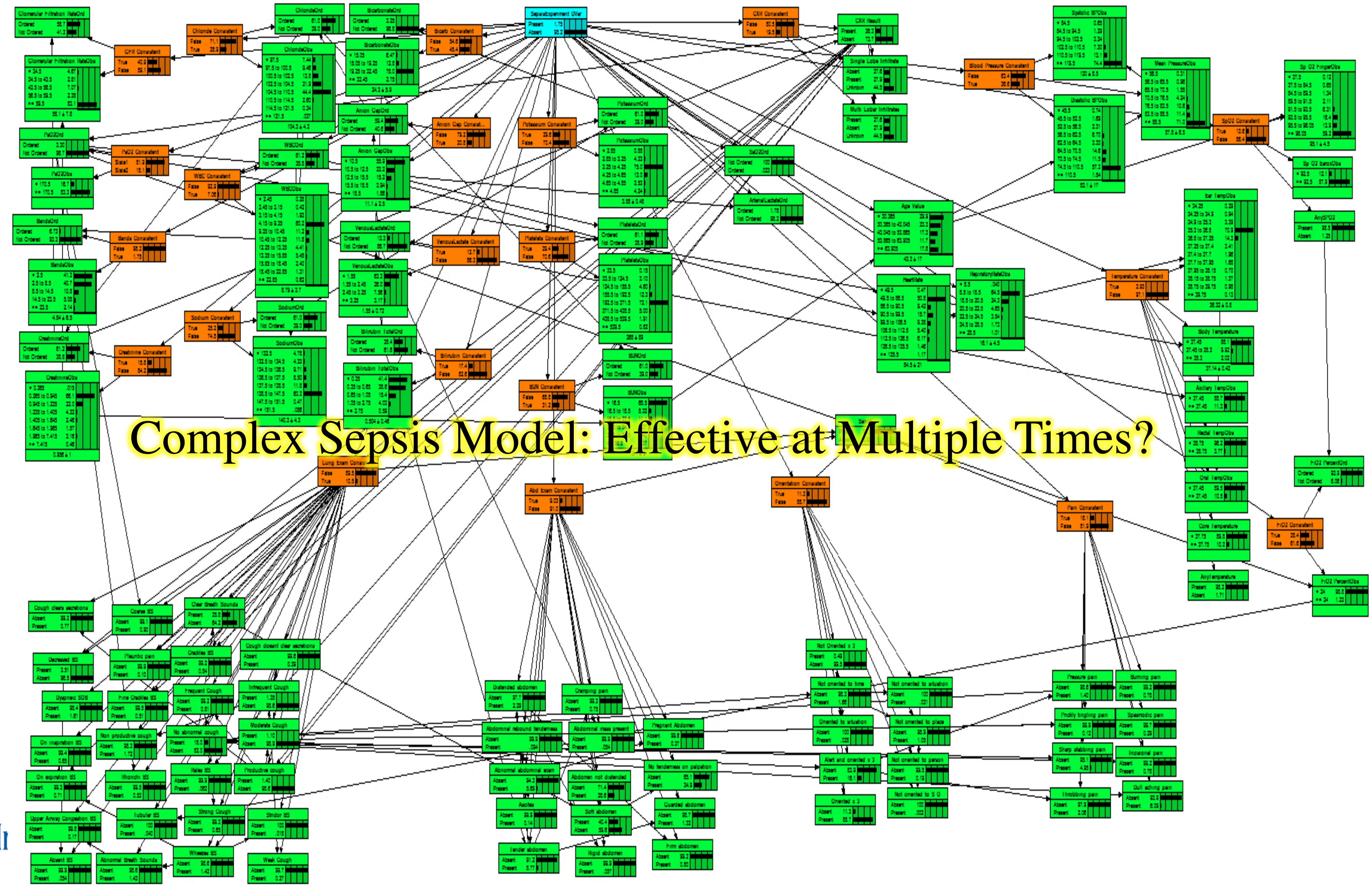
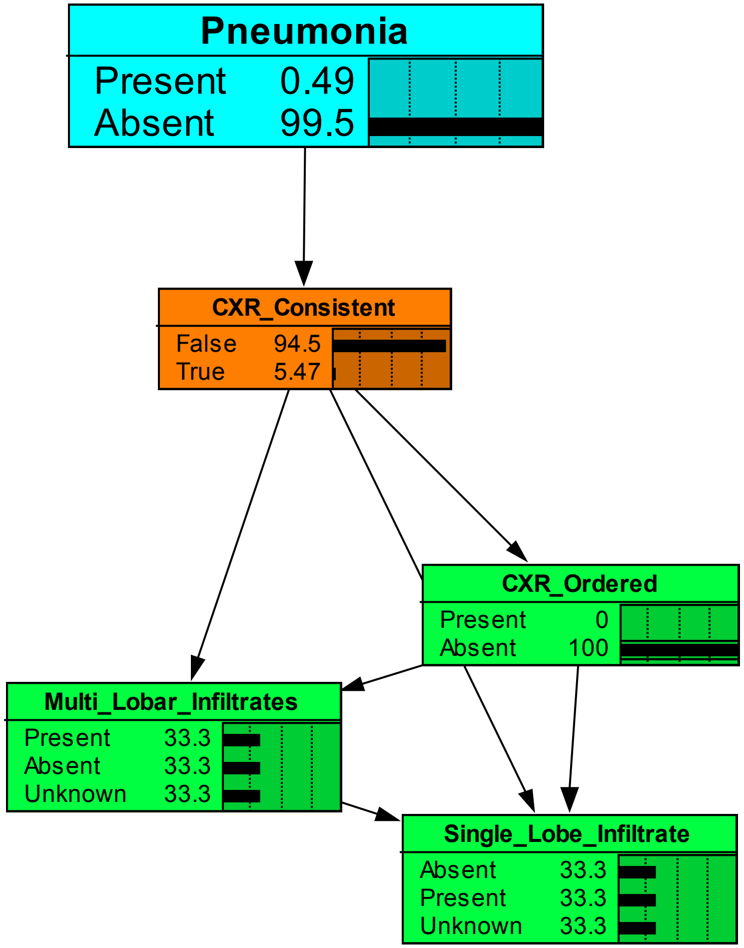
Sepsis Model: Extending Its Coverage



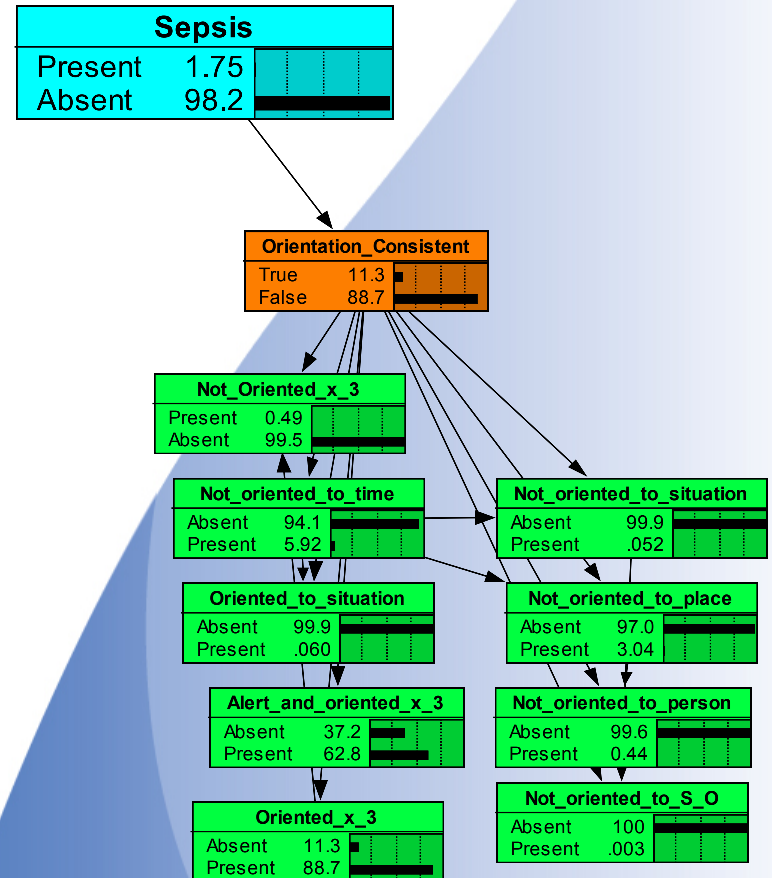
Complex Sepsis Model: Effective at Multiple Times?

Adding Semantics to the Model

Saying "Findings are consistent with Diagnosis"



"Chest X-ray Results consistent with Pneumonia"



"Mental Status consistent with Sepsis"

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Conclusion

"All models are wrong; some models are useful."
Attributed to statistician George Box

- Probabilistic Models have a role in clinical care
- Enterprise Data Warehouses can contribute to Model development
- Stored Medical Knowledge (in the form of Ontologies) can accelerate Modeling
- Bayesian Models can flexibly represent a variety of clinical conditions.

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Comments and Questions

Questions???

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