Probabilistic Reasoning for Medical Decision Support

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Overview

Predictive & diagnostic models for medical decision making using machine learning in

- Penetrating trauma
- Chronic kidney disease

Machine learning models

- Mathematical models that
  - capture/“learn’’ patterns in existing data
  - utilize learned patterns to solve new problems
- Used successfully for
  - predicting protein secondary structure
  - diagnosing community acquired pneumonia
  - diagnosing penetrating trauma injuries
  - analyzing HIV mutation changes based on treatment history
  - genome-wide association studies of single nucleotide polymorphisms (SNPs) that affect disease susceptibility

Penetrating trauma

Computerized trauma diagnostic decision support useful for

- initial patient assessment (by EMTs or ED physicians)
- analysis of decision making after treatment
- training or teaching
- research (e.g. DoD virtual autopsy, virtual soldier projects)

Penetrating trauma

Problem

Performing computer-aided assessment of penetrating trauma in the face of

- uncertainty about the extent of damage associated with a mechanism of injury
- varying amounts of information about patient findings (signs, symptoms, and test results)

Penetrating trauma

Possible solutions

- Rule-based reasoning (rules relating external wounds, injuries, signs and symptoms)
- Combine:
  - simple 3D geometric reasoning about mechanisms of injury and anatomical structures affected

    (O Ogunyemi, Journal of Biomedical Informatics 2006)
  - probabilistic reasoning about consequences of injury using Bayesian networks

Resulting system: TraumaSCAN-Web

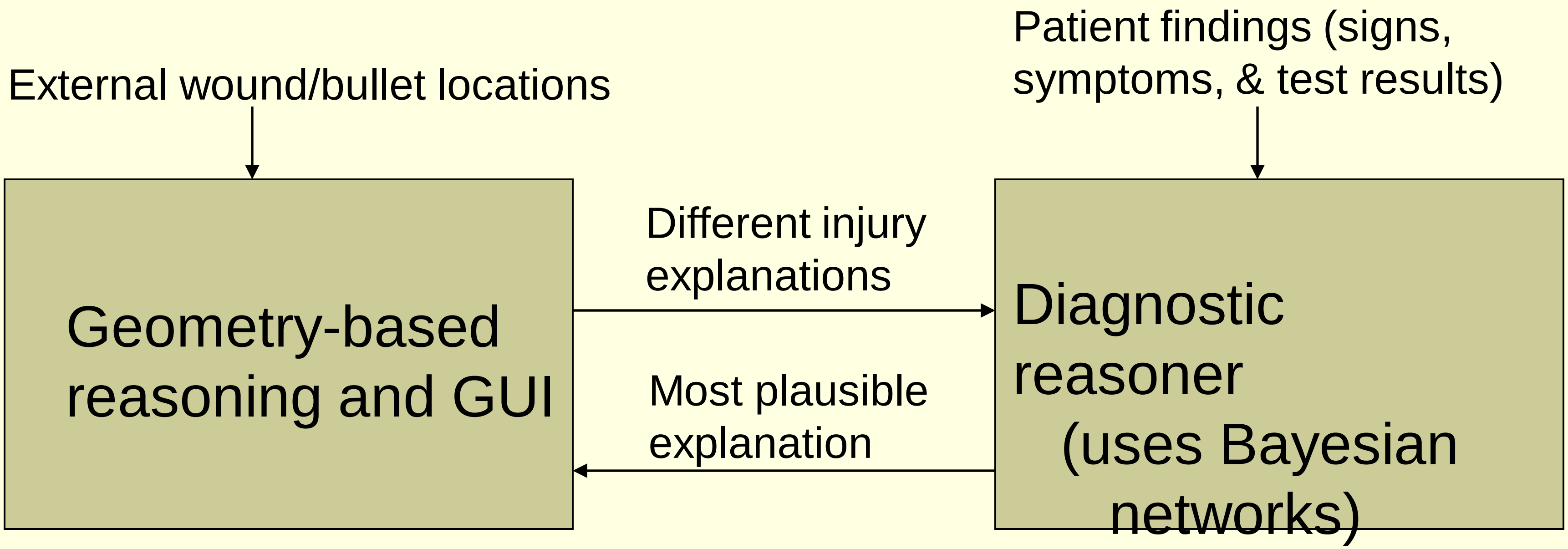
Penetrating trauma

TraumaSCAN-Web:

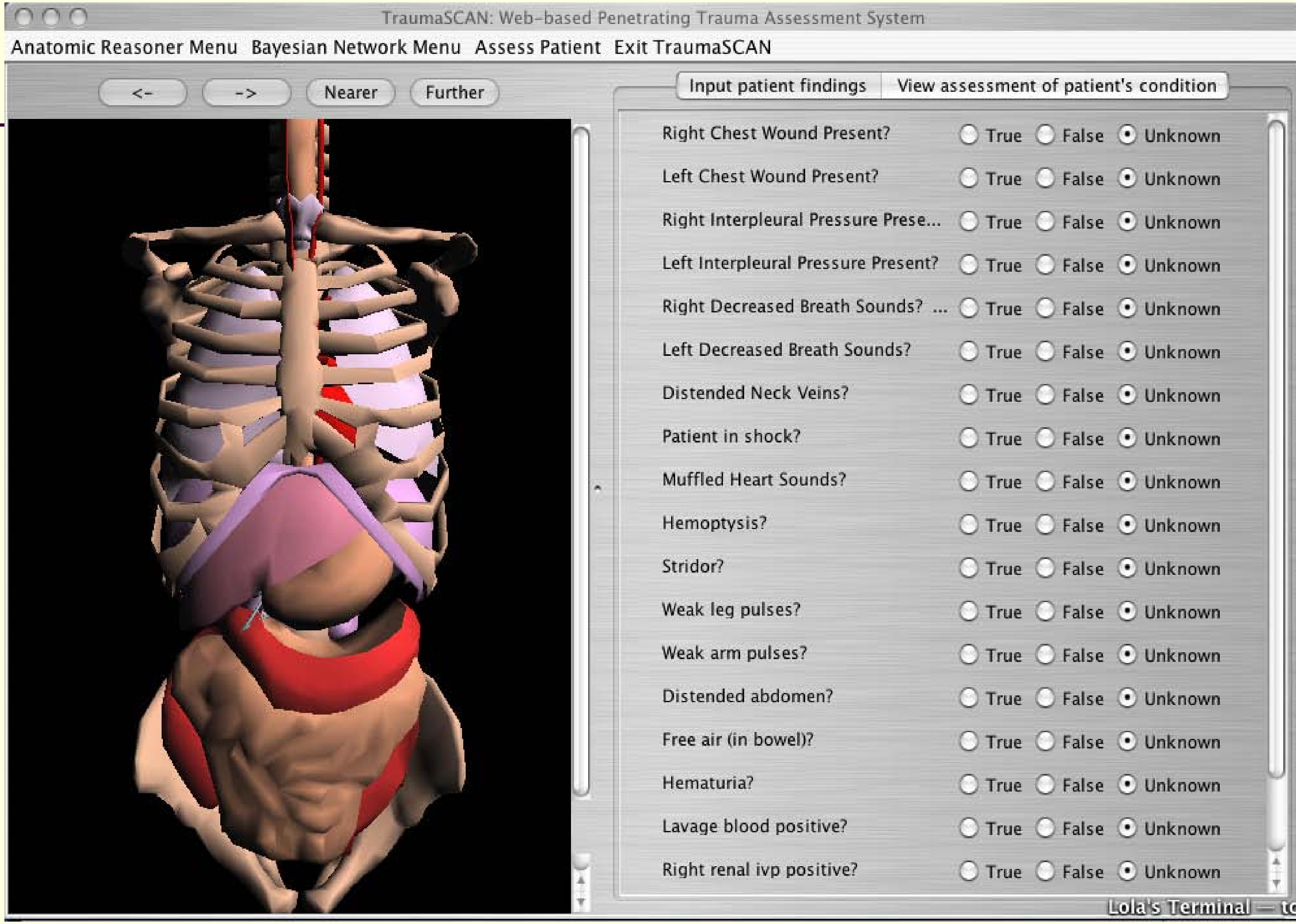
- platform-independent diagnostic decision support for chest & abdominal penetrating trauma
- uses Java3D (Java API for 3D graphics) for geometric modeling and algorithms
- 3D models of anatomic structures from Viewpoint DataLabs
- diagnostic reasoner implemented using SamIAm Bayesian network API (UCLA)
- provides diagnostic decision support on 24 conditions resulting from gunshot/stab trauma to chest and abdomen

Penetrating trauma

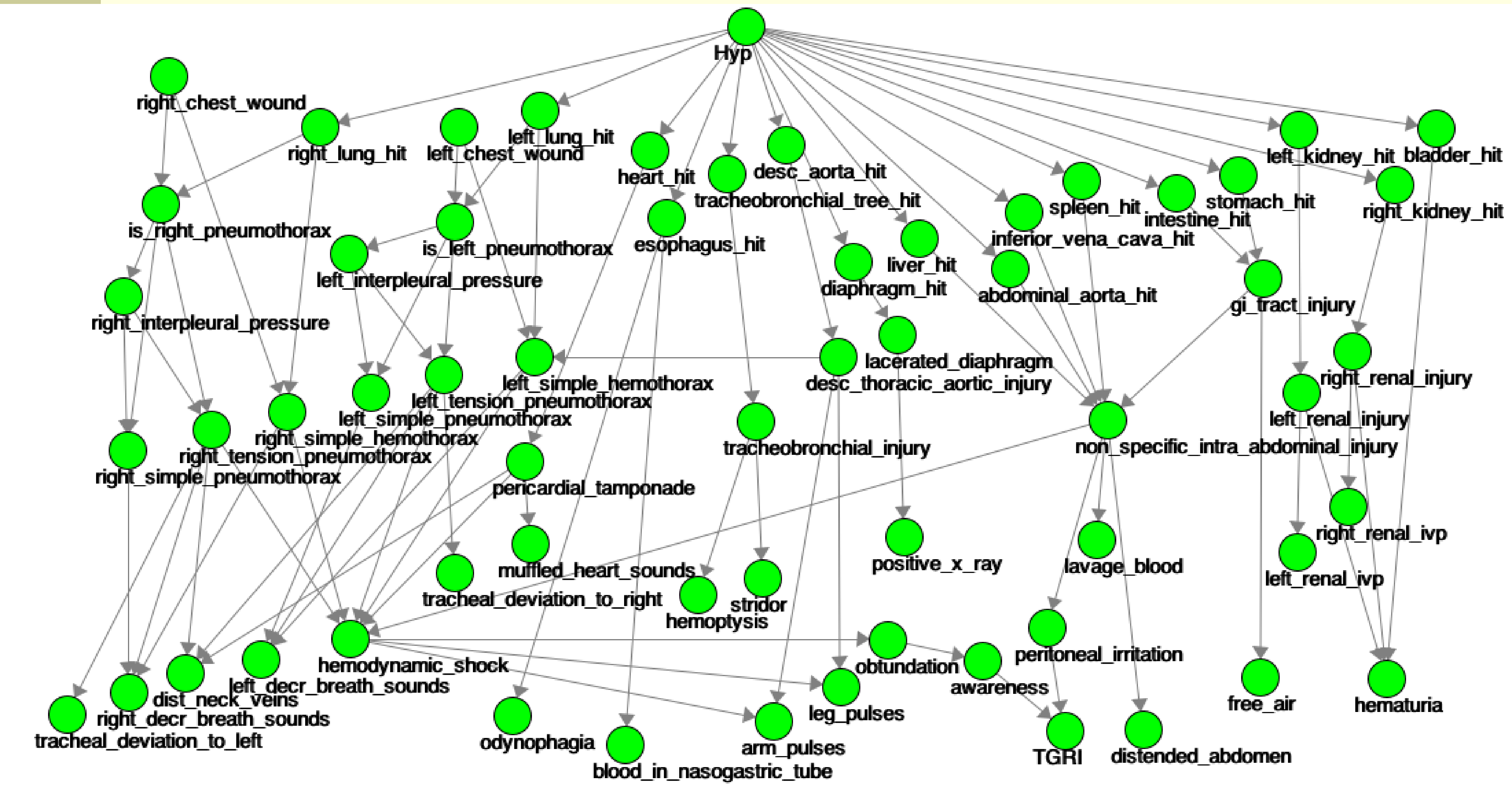
TraumaSCAN-Web Architecture:

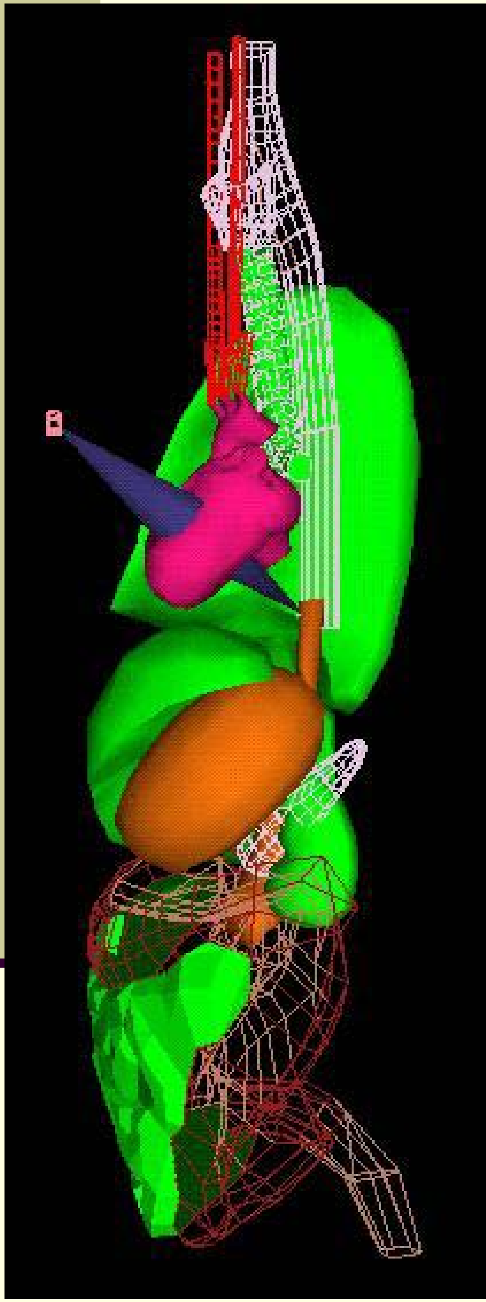


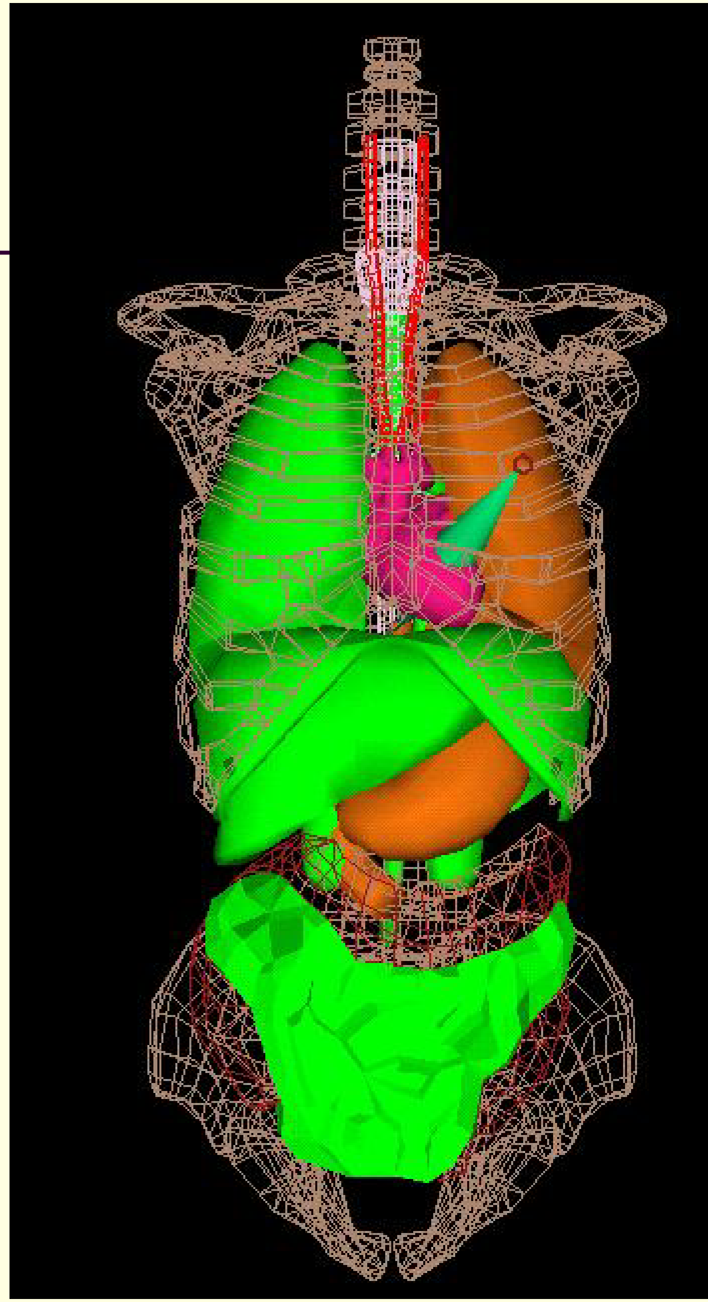
Interface: Virtual Anatomy & Bayesian network



Bayesian Network Directed Acyclic Graph







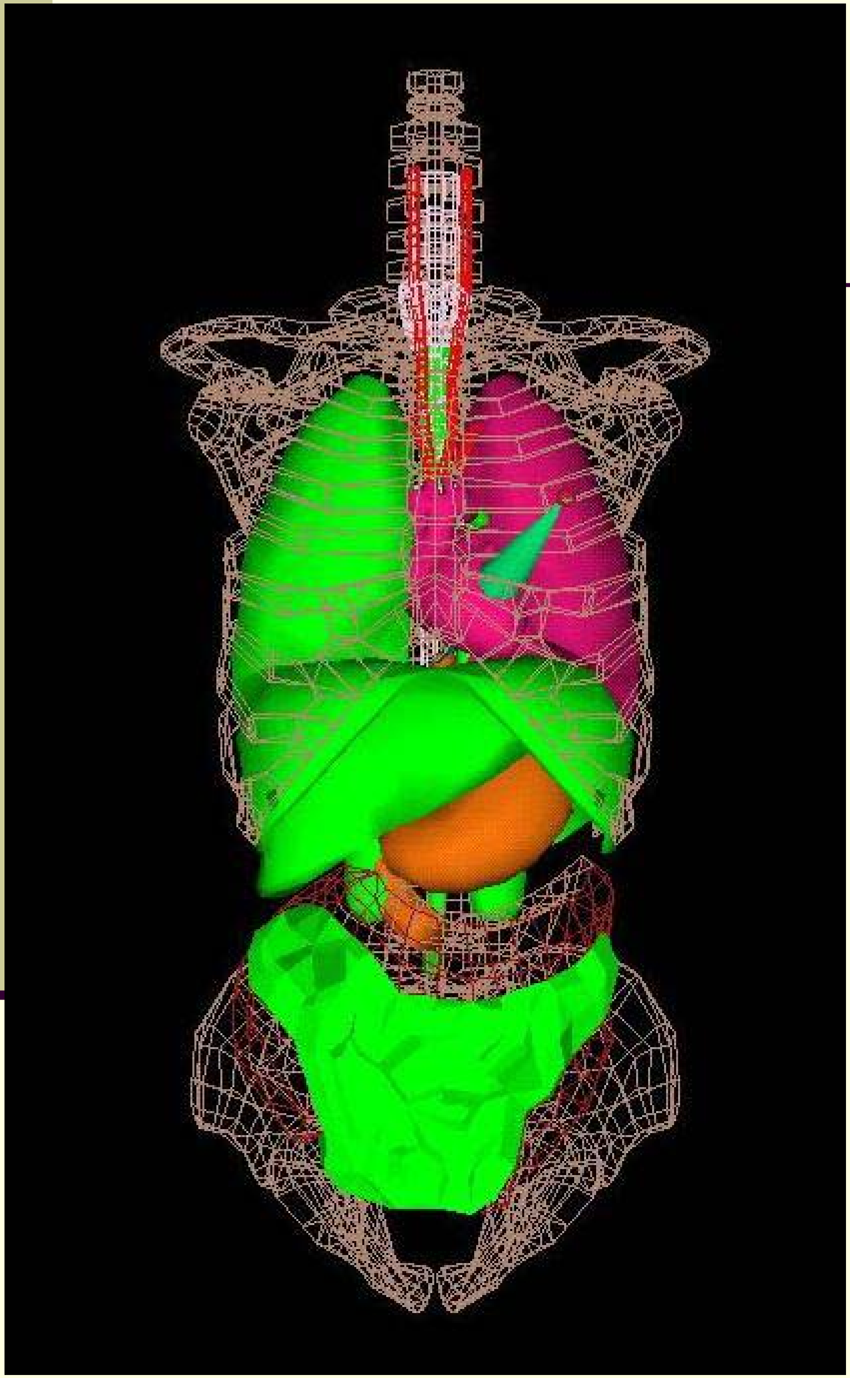
0 <= X < 25%

25 <= X < 50%

50 <= X < 75%

75 <= X <=100%

Bayesian network posterior probabilities of organ injury before patient findings observed



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25 <= X < 50%

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Bayesian network posterior probabilities of organ injury after
left decreased breath sounds
observed

Left decreased breath sounds imply left lung injury

Penetrating trauma

Evaluation

- Good diagnostic accuracy results on 190 gunshot & stab injury cases from Brigham & Women's and MCP-Hahnemann Hospitals

  (M Matheny, O Ogunyemi, P Rice, J Clarke, Proc AMIA 2005)

- Good diagnostic accuracy results on 637 gunshot and stab injury cases from Brigham & Women's, Mass General and MCP-Hahnemann Hospitals

  (B Ahmed, M Matheny, P Rice, J Clarke, O Ogunyemi, Journal of Biomedical Informatics 2009)

Penetrating trauma

Collaborators

- John R. Clarke, MD, FACS
- Phillip Rice, MD
- Michael Matheny, MD
- Bilal Ahmed, MD

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Predicting Chronic Kidney Disease in HIV-Positive Individuals

Chronic Kidney Disease

Overview:

- Evidence of kidney damage that persists for 3 or more months (National Kidney Foundation)
- Severity is graded based on renal function using estimates of creatinine clearance or glomerular filtration rate (GFR)
- Occurs in 30% of individuals with HIV

Chronic Kidney Disease

Stage	**Description**	**GFR (ml/min per 1.73 m^2)**
I	Kidney damage with normal/increased GFR	>= 90
II	Kidney damage with mildly decreased GFR	60-89
III	Moderately decreased GFR	30-59
IV	Severely decreased GFR	15-29
V	Kidney failure	<15 (or dialysis)

Chronic Kidney Disease

Study goals:

- Develop computerized models for predicting the two- and five-year risk of developing Stage I CKD in HIV-positive individuals
- Create web-based tool to help physicians identify HIV-positive patients at high-risk of developing CKD
- Identify which HIV-medications are least nephrotoxic
- Identify minimum set of patient-related variables/features that predict CKD

Chronic Kidney Disease

Study goals, contd.:

- Compare predictive models based on
  - Artificial neural networks
  - Bayesian networks
  - Support vector machines
  - Logistic regression
- Determine whether routinely collected clinical measures are sufficient for prediction

Chronic Kidney Disease

Related work

- Decision tree models for predicting end-stage renal disease (Dimitrov et al 2003)
- NEOERICA: automated identification of patients with CKD from electronic medical records (de Lusignan et al 2005)
- SCORED: logistic regression model for identifying existing, undiagnosed Stage III CKD on NHANES data (Bang et al 2007)
- Logistic regression model for predicting 10 year risk of developing Stage III CKD in general population (Kshirsagar et al 2008)

Chronic Kidney Disease

Risk Factors

Gender	Age	Ethnicity
Smoking status	Substance abuse	Body mass index
Fasting blood sugar	Cardiovascular disease	Diagnosed diabetes
LDL	HDL	Blood pressure
Triglycerides	Hypertension	Dyslipidemia
CD4 count	HIV RNA Titer	NSAIDS
MYH9 gene mutations	Reverse transcriptase inhibitors (RTI)	
Protease inhibitors	Fusion inhibitors	Non-nucleoside RTI

Chronic Kidney Disease

Preliminary study of 2-year CKD risk prediction using machine learning in 92 HIV-positive patients shows promise

(O Ogunyemi, C Ani, F Yemofio, W Jordan, K Norris, Medinfo 2010)

Collaborators

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