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:

- External wound/bullet locations
- Geometry-based reasoning and GUI
- Patient findings (signs, symptoms, & test results)
- Diagnostic reasoner (uses Bayesian networks)

Different injury explanations
Most plausible explanation
Interface: Virtual Anatomy & Bayesian network
Bayesian Network Directed Acyclic Graph
Bayesian network posterior probabilities of organ injury before patient findings observed.
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

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
<th>GFR (ml/min per 1.73 m²)</th>
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<tbody>
<tr>
<td>I</td>
<td>Kidney damage with normal/increased GFR</td>
<td>&gt;= 90</td>
</tr>
<tr>
<td>II</td>
<td>Kidney damage with mildly decreased GFR</td>
<td>60-89</td>
</tr>
<tr>
<td>III</td>
<td>Moderately decreased GFR</td>
<td>30-59</td>
</tr>
<tr>
<td>IV</td>
<td>Severely decreased GFR</td>
<td>15-29</td>
</tr>
<tr>
<td>V</td>
<td>Kidney failure</td>
<td>&lt;15 (or dialysis)</td>
</tr>
</tbody>
</table>
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
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

<table>
<thead>
<tr>
<th>Risk Factors</th>
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<tbody>
<tr>
<td>Gender</td>
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<tr>
<td>Age</td>
</tr>
<tr>
<td>Ethnicity</td>
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<tr>
<td>Smoking status</td>
</tr>
<tr>
<td>Substance abuse</td>
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<tr>
<td>Body mass index</td>
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<tr>
<td>Fasting blood sugar</td>
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<tr>
<td>Cardiovascular disease</td>
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<tr>
<td>Diagnosed diabetes</td>
</tr>
<tr>
<td>LDL</td>
</tr>
<tr>
<td>HDL</td>
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<tr>
<td>Blood pressure</td>
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<tr>
<td>Triglycerides</td>
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<tr>
<td>Hypertension</td>
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<tr>
<td>Dyslipidemia</td>
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<tr>
<td>CD4 count</td>
</tr>
<tr>
<td>HIV RNA Titer</td>
</tr>
<tr>
<td>NSAIDS</td>
</tr>
<tr>
<td>MYH9 gene mutations</td>
</tr>
<tr>
<td>Reverse transcriptase inhibitors (RTI)</td>
</tr>
<tr>
<td>Protease inhibitors</td>
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<tr>
<td>Fusion inhibitors</td>
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<tr>
<td>Non-nucleoside RTI</td>
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</tbody>
</table>
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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- Wilbert Jordan, MD
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