Healthcare System Dynamics

http://HealthcareSystemDynamics.org

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Big Data to Knowledge (BD2K), NIH/NCI U01 CA198934

Healthcare System Dynamics

Clinical data reflect both patients' health AND their interactions with the healthcare system.

<table>
<thead>
<tr>
<th>Patient Pathophysiology</th>
<th>Healthcare System Dynamics</th>
<th>Data Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient Demographics</td>
<td>Number of Observations</td>
<td>Data Entry Errors</td>
</tr>
<tr>
<td>Diagnoses</td>
<td>Time of Day of Observations</td>
<td>Dictation Mistakes</td>
</tr>
<tr>
<td>Laboratory Test Results</td>
<td>Time Between Observations</td>
<td>Data Compression Loss</td>
</tr>
<tr>
<td>Vital Signs</td>
<td>Cost of a Test or Treatment</td>
<td>Unstructured Data</td>
</tr>
<tr>
<td>Genetic Markers</td>
<td>Clinical Setting / Clinician Type</td>
<td>Missing Data</td>
</tr>
</tbody>
</table>

Healthcare System Dynamics

Electronic Health Record Data

<table>
<thead>
<tr>
<th>HealthCare System Dynamics</th>
<th>Normal</th>
<th>Abnormal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Best Outcomes</td>
<td>Moderate Outcomes</td>
</tr>
<tr>
<td>Abnormal</td>
<td>Moderate Outcomes</td>
<td>Worst Outcomes</td>
</tr>
</tbody>
</table>

Patient Pathophysiology

Clinical Encounter

Patient

Clinician

EHR
Daily HSD Cycles in Clinical Data

Weekly HSD Cycles in Clinical Data
Yearly HSD Cycles in Clinical Data

HSD Impact on Time Intervals between Visits
Using HSD To Predict Outcomes

Survival 3 Years After a WBC Test
Fraction of Patients with WBC by Value and Hour

3-Year Survival After a WBC by Value and Hour
Fraction of Patients with WBC by Value and Weekday

3-Year Survival After a WBC by Value and Weekday
Predicting Survival from **Ordering** a Lab Test

Predicting Survival Using **Lab Value & HSD**
30 Day Readmission Rate After a WBC Test

Using HSD To Derive Normal Ranges
Deriving Normal Ranges of Lab Test Values


Deriving Normal Ranges by Age Group
Three Types of Laboratory Tests

Lab Categories

WBC
HDL
Hgb
A1c

Normalized Time to Repeat

Normalized Value
Three Types of Laboratory Tests

![Graph showing Lab Categories and hCG (Human Chorionic Gonadotropin) normalized values over time.]

Predicting Survival Using “Fact Count”
Fact Count (over 8.5 years) by Age & Gender

Horizontal blue curves with rectangular labels are five year fact count percentiles. Vertical red curves with hexagonal labels are three year survival curves. Data are from BWH and MGH from 7/28/2001 to 7/27/2009. All patients had at least one fact between 7/28/2005 and 7/27/2006. The "current" age is the patient age on 7/27/2006. This chart represents only male patients.
Horizontal blue curves with rectangular labels are five year fact count percentiles. Vertical red curves with hexagonal labels are three year survival curves. Data are from BWH and MGH from 7/28/2001 to 7/27/2009. All patients had at least one fact between 7/28/2005 and 7/27/2006. The “current” age is the patient age on 7/27/2006. This chart represents only male patients.
Fact Count Growth & Survival Chart (Female)

Horizontal blue curves with rectangular labels are five year fact count percentiles. Vertical red curves with hexagonal labels are three year survival curves. Data are from BWH and MGH from 7/28/2001 to 7/27/2009. All patients had at least one fact between 7/28/2005 and 7/27/2006. The "current" age is the patient age on 7/27/2006. This chart represents only female patients.

Adding HSD To i2b2
Adding HSD to i2b2 Using Sci2 Visualization Platform

Ontology for Visualizing HSD
Informatics for Integrating Biology and the Bedside
https://www.i2b2.org

Interactive HSD Visualizations
Science of Science (Sci2)
https://sci2.cns.iu.edu

HSD Visualization Ontology
Clinical Data Repository (i2b2)
Selected Patients & Concepts
HSD Data Cube (XML)
HSD Data Visualization (Sci2)

Extend Ontology
Refine Queries
Learning from Visualization of HSD

HSD Ontology for i2b2
Sci2 – WBC Survival by Time of Day Heatmap

Sci2 – WBC Survival by Time of Day Heatmap
We need your help!

- Try our i2b2 demo & download HSD ontology
  http://HealthcareSystemDynamics.org
- Participate in our upcoming Focus Groups
- Share with us references of similar work
- Feedback, suggestions, questions, etc.
  weber@hms.harvard.edu

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Extras

Clinical Trial vs EHR Data

Clinical Trial (With 6 Month Visits) vs Hospital Electronic Health Record

- Number of Visits vs Months Since Data Collection Began
- Percent of Visits vs Days Since Last Visit
- WBC Count vs Months Since Data Collection Began
Survival by WBC Value and HSD Dimensions

Survival by WBC Value and HSD Dimensions
Survival 3 Years After a WBC Test
(White, Male, 50-69 Years; Using Last WBC Between 7/28/05 and 7/27/06)

### WBC Value

<table>
<thead>
<tr>
<th>Result Time</th>
<th>Low</th>
<th>Normal</th>
<th>High</th>
<th>Any</th>
<th>Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>12a-8a</td>
<td>46.56%</td>
<td>82.91%</td>
<td>65.90%</td>
<td>76.43%</td>
<td>3649</td>
</tr>
<tr>
<td>8a-4p</td>
<td>79.61%</td>
<td>92.81%</td>
<td>81.71%</td>
<td>90.73%</td>
<td>14534</td>
</tr>
<tr>
<td>4p-12a</td>
<td>81.99%</td>
<td>94.29%</td>
<td>85.74%</td>
<td>92.96%</td>
<td>4930</td>
</tr>
<tr>
<td>Any</td>
<td>73.17%</td>
<td>91.79%</td>
<td>78.11%</td>
<td>88.95%</td>
<td>23113</td>
</tr>
<tr>
<td><strong>Patients</strong></td>
<td>1286</td>
<td>18775</td>
<td>3052</td>
<td>23113</td>
<td></td>
</tr>
</tbody>
</table>

### Time Since Last WBC

<table>
<thead>
<tr>
<th>WBC Value</th>
<th>Low</th>
<th>Normal</th>
<th>High</th>
<th>Any</th>
<th>Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1 Day</td>
<td>47.21%</td>
<td>85.04%</td>
<td>70.35%</td>
<td>78.92%</td>
<td>3501</td>
</tr>
<tr>
<td>&lt; 1 Year</td>
<td>72.88%</td>
<td>89.98%</td>
<td>79.22%</td>
<td>87.43%</td>
<td>13225</td>
</tr>
<tr>
<td>&gt; 1 Year</td>
<td>96.52%</td>
<td>97.83%</td>
<td>94.12%</td>
<td>97.59%</td>
<td>6387</td>
</tr>
<tr>
<td>Any</td>
<td>73.17%</td>
<td>91.79%</td>
<td>78.11%</td>
<td>88.95%</td>
<td>23113</td>
</tr>
<tr>
<td><strong>Patients</strong></td>
<td>1286</td>
<td>18775</td>
<td>3052</td>
<td>23113</td>
<td></td>
</tr>
</tbody>
</table>

Survival 3 Years After a WBC Test
(White, Male, 50-69 Years; Using Last WBC Between 7/28/05 and 7/27/06)

### Repeat Interval

#### WBC Value

<table>
<thead>
<tr>
<th>Repeat Interval</th>
<th>Result Time</th>
<th>Low</th>
<th>Normal</th>
<th>High</th>
<th>Any</th>
<th>Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1 Day</td>
<td>12a-8a</td>
<td>43.33%</td>
<td>84.68%</td>
<td>63.24%</td>
<td>76.39%</td>
<td>1830</td>
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<tr>
<td></td>
<td>8a-4p</td>
<td>54.55%</td>
<td>86.61%</td>
<td>79.40%</td>
<td>83.15%</td>
<td>1442</td>
</tr>
<tr>
<td></td>
<td>4p-12a</td>
<td>77.30%</td>
<td>67.53%</td>
<td>72.49%</td>
<td></td>
<td>229</td>
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<tr>
<td>&lt; 1 Year</td>
<td>12a-8a</td>
<td>47.83%</td>
<td>79.58%</td>
<td>66.67%</td>
<td>74.39%</td>
<td>1644</td>
</tr>
<tr>
<td></td>
<td>8a-4p</td>
<td>76.96%</td>
<td>90.73%</td>
<td>80.80%</td>
<td>88.53%</td>
<td>8812</td>
</tr>
<tr>
<td></td>
<td>4p-12a</td>
<td>81.65%</td>
<td>92.99%</td>
<td>86.01%</td>
<td>91.69%</td>
<td>2769</td>
</tr>
<tr>
<td>&gt; 1 Year</td>
<td>12a-8a</td>
<td>95.65%</td>
<td>96.97%</td>
<td>96.00%</td>
<td></td>
<td>175</td>
</tr>
<tr>
<td></td>
<td>8a-4p</td>
<td>97.30%</td>
<td>98.13%</td>
<td>91.98%</td>
<td>97.83%</td>
<td>4280</td>
</tr>
<tr>
<td></td>
<td>4p-12a</td>
<td>92.68%</td>
<td>97.35%</td>
<td>96.67%</td>
<td>97.20%</td>
<td>1932</td>
</tr>
<tr>
<td>Any</td>
<td>73.17%</td>
<td>91.79%</td>
<td>78.11%</td>
<td>88.95%</td>
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<td></td>
<td></td>
</tr>
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</table>
Age-Fact Count Disease Profiles

Each point is the average age and fact count percentile of patients with a diagnosis.

Cosmetic surgery vs. vascular catheter: same patient age, different health statuses.