Big Data oder Wissen als Spezialanfertigung – Transparenz und Zuverlässigkeit

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Digitalization of clinical medicine

- Stage I: Digitizing patient medical data
  - EHRs, EMRs, Health Apps, ...

- Stage II: Digitizing clinical workflows
  - In-patient, out-patient, home

- Stage III: Digitizing medical knowledge
  - Big data vs. knowledge design

Clinical decision support—Applying knowledge to data

- Patient safety
- Quality assurance
- Cost reduction
- studies in Colorado and Utah and in New York (1997)
  - errors in the delivery of health care leading to the death of as many as 98,000 US citizens annually

- causes of errors
  - error or delay in diagnosis
  - failure to employ indicated tests
  - use of outmoded tests or therapy
  - failure to act on results of testing or monitoring
  - error in the performance of a test, procedure, or operation
  - error in administering the treatment
  - error in the dose or method of using a drug
  - avoidable delay in treatment or in responding to an abnormal test
  - inappropriate (not indicated) care
  - failure of communication
  - equipment failure

- prevention of errors
  - we must systematically design safety into processes of care
Big data vs. knowledge design

IBM Watson Health vs. Medexter Health Knowledge
Big data vs. knowledge design

- Big raw data
  - Data mining
    - CDS
      - Induction
        - Empirical
  - Structured knowledge design
    - Knowledge-based systems

- Big document data
  - Text mining
    - CDS
      - Induction
        - Mixed

- Structured knowledge design
  - Knowledge-based systems
    - CDS
      - Deduction
        - Axiomatic
IBM Watson Health vs. Medexter Health Knowledge

**Raw Data**
- Machine learning

**Implicit**
- Cognitive engine
- Based on associations
- Empirical cases
- Partially transparent

**Explicit**
- Knowledge engine
- Based on relationships
- Common, rare, and "impossible" events
- Transparent

**Structured Knowledge**
- Designed knowledge
- Causal knowledge
- Machine learning results

**Processing Engine**
Hepaxpert

Knowledge-based interpretation of hepatitis serology test results
Automated interpretation of hepatitis serology test results

- includes frequent, rare, as well as inconsistent combinations
- complete coverage of the problem domains
- e.g., hepatitis B serology: about 150 rules in 3 layers for 61,440 possible combinations
Diagnostisches Profil Hepatitis B

Dieser serologische Verlauf tritt bei 75-80% der Patienten mit akuter Hepatitis B auf.

Profil der serologischen Marker eines chronischen Trägers:

keine Serokonversion [Anti-HBe]

Infekionsstatus

- Infektions-
  potentiell
  - nicht infektiös
- immun

Infekions-
  - jahre
  - 2 Wochen - 3 Monate
  - 3 - 6 Monate
  - Jahre

Abbott

Serologische Marker Hepatitis B

- HBV-DNA
- HBsAg
- Anti-HBe
- Anti-HBs
Inkubation

persistierende Hepatitis B Virusinfektion

0

HBsAg

HBeAg

Anti-HBc

IgM-anti-HBc

I

HBsAg

HBeAg

Anti-HBc

IgM-anti-HBc

II

HBsAg

HBeAg

Anti-HBc

Anti-HBe

IgM-anti-HBc

III

HBsAg

HBeAg

Anti-HBc

Anti-HBe

IgM-anti-HBc

IV

HBsAg

HBeAg

Anti-HBe

HBeAg

Anti-HBe

IgM-anti-HBc

IgM-anti-HBc
One of the rules to interpret clinically relevant findings (rule premises form equivalent classes)

RULE 103:

IF one of the following 100 combinations

<table>
<thead>
<tr>
<th>HBsAg</th>
<th>anti-HBs</th>
<th>anti-HBc</th>
<th>IgM anti-HBc</th>
<th>HBeAg</th>
<th>anti-HBe</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>•</td>
<td>+</td>
<td>- ±</td>
<td>•</td>
<td>+</td>
</tr>
<tr>
<td>+</td>
<td>•</td>
<td>+</td>
<td>+ • ±</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

THEN

The simultaneous occurrence of HBe-antigen and anti-HBs antibodies is a rare event in the natural course of a hepatitis B virus infection. This constellation of findings may be attributed to one of the following causes: (a) circulating HBsAg-anti-HBs immune complexes, (b) hepatitis B virus infection coinciding with a hepatitis B vaccination or injection of HB-hyperimmune globulin, or (c) reinfection with a hepatitis virus B with a different HBsAg subtype. Blood and secretions (saliva, sperm, breast milk) of such patients are to be regarded as infectious.
Regel zur Interpretation von „inkonsistente Befunde“

REGEL 3:

WENN

<table>
<thead>
<tr>
<th>HBsAg</th>
<th>anti-HBs</th>
<th>anti-HBc</th>
<th>IgM anti-HBc</th>
<th>HBeAg</th>
<th>anti-HBe</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>± ± ± ±</td>
<td>± ± ± ±</td>
<td>± ± ± ±</td>
<td>+</td>
<td>± ± ± ±</td>
</tr>
<tr>
<td>− ±</td>
<td>+ − ± ±</td>
<td>− ± ± ±</td>
<td>− ± ± ±</td>
<td>− ±</td>
<td>± ± ± ±</td>
</tr>
</tbody>
</table>

DANN

Häufigkeit des Auftretens von Befundmustern und Regeln für die Hepatitis B im Verlauf von 20 Monaten

<table>
<thead>
<tr>
<th>Monate</th>
<th>Anforderungen</th>
<th>Muster (von 4.095)</th>
<th>Regeln (von 105)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0 0,0%</td>
<td>0 0%</td>
</tr>
<tr>
<td>1</td>
<td>524</td>
<td>25 0,6%</td>
<td>19 18%</td>
</tr>
<tr>
<td>2</td>
<td>1.084</td>
<td>39 1,0%</td>
<td>28 27%</td>
</tr>
<tr>
<td>3</td>
<td>1.665</td>
<td>52 1,3%</td>
<td>32 30%</td>
</tr>
<tr>
<td>4</td>
<td>2.169</td>
<td>65 1,6%</td>
<td>35 33%</td>
</tr>
<tr>
<td>5</td>
<td>2.842</td>
<td>75 1,8%</td>
<td>37 35%</td>
</tr>
<tr>
<td>6</td>
<td>3.402</td>
<td>83 2,0%</td>
<td>40 38%</td>
</tr>
<tr>
<td>7</td>
<td>4.037</td>
<td>87 2,1%</td>
<td>41 39%</td>
</tr>
<tr>
<td>8</td>
<td>4.559</td>
<td>93 2,3%</td>
<td>42 40%</td>
</tr>
<tr>
<td>9</td>
<td>5.115</td>
<td>98 2,4%</td>
<td>45 43%</td>
</tr>
<tr>
<td>10</td>
<td>5.624</td>
<td>102 2,5%</td>
<td>46 44%</td>
</tr>
<tr>
<td>11</td>
<td>6.021</td>
<td>103 2,5%</td>
<td>46 44%</td>
</tr>
<tr>
<td>12</td>
<td>6.399</td>
<td>105 2,6%</td>
<td>47 45%</td>
</tr>
<tr>
<td>13</td>
<td>6.896</td>
<td>112 2,7%</td>
<td>50 48%</td>
</tr>
<tr>
<td>14</td>
<td>7.575</td>
<td>115 2,8%</td>
<td>50 48%</td>
</tr>
<tr>
<td>15</td>
<td>8.219</td>
<td>118 2,9%</td>
<td>50 48%</td>
</tr>
<tr>
<td>16</td>
<td>8.699</td>
<td>124 3,0%</td>
<td>51 49%</td>
</tr>
<tr>
<td>17</td>
<td>9.327</td>
<td>129 3,2%</td>
<td>51 49%</td>
</tr>
<tr>
<td>18</td>
<td>9.890</td>
<td>131 3,2%</td>
<td>51 49%</td>
</tr>
<tr>
<td>19</td>
<td>10.439</td>
<td>134 3,3%</td>
<td>53 50%</td>
</tr>
<tr>
<td>20</td>
<td><strong>11.303</strong></td>
<td><strong>135 3,3%</strong></td>
<td><strong>53 50%</strong></td>
</tr>
</tbody>
</table>
Clinical alerts

Ward-specific, highly-adaptive reminders
Inflammation Monitoring and Alerts

Leukocyte value indicates leukocytosis

Persistent leukocytosis

Further increase of leukocytes

Further increase of CRP

Moderately increased CRP

Leukocytes [μl]:
- Normal range: 4.0 – 10.0

CRP [μg/l]:
- Normal range: 0 – <20.0

Hospital admittance
### Clinical Alerts

<table>
<thead>
<tr>
<th>Generated</th>
<th>Messages</th>
</tr>
</thead>
<tbody>
<tr>
<td>04-18-2015 13:02</td>
<td>Further increase of CRP</td>
</tr>
<tr>
<td>04-18-2015 13:02</td>
<td>Persistent leukocytosis</td>
</tr>
<tr>
<td>04-17-2015 12:32</td>
<td>Further increase of leukocytes</td>
</tr>
<tr>
<td>04-15-2015 13:37</td>
<td>Leukocyte value indicates leukocytosis</td>
</tr>
<tr>
<td>04-15-2015 13:37</td>
<td>Moderately increased CRP</td>
</tr>
</tbody>
</table>

**HEMATOLOGICAL PROFILE**

<table>
<thead>
<tr>
<th>Date</th>
<th>Leukocytes</th>
<th>Hemoglobin</th>
<th>CRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>04-18-2015</td>
<td>19.4 /ml</td>
<td>-</td>
<td>169 mg/l</td>
</tr>
<tr>
<td>04-17-2015</td>
<td>20.1 /ml</td>
<td>-</td>
<td>105 mg/l</td>
</tr>
<tr>
<td>04-16-2015</td>
<td>17.5 /ml</td>
<td>-</td>
<td>98 mg/l</td>
</tr>
<tr>
<td>04-15-2015</td>
<td>17.1 /ml</td>
<td>-</td>
<td>80 mg/l</td>
</tr>
<tr>
<td>04-14-2015</td>
<td>21.5 /ml</td>
<td>-</td>
<td>88 mg/l</td>
</tr>
</tbody>
</table>

**BIOCHEMICAL PROFILE**

<table>
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Summary

- **Big data mining**
  - Huge amount of data available
  - Erroneous cases are usually part of the data
  - Empirical data are incomplete
  - Low transparency

- **Big document mining**
  - Huge amount of documents available
  - Documents are humanly preprocessed and checked
  - Learning from erroneous or outdated documents
  - Medium transparency

- **Knowledge design**
  - Carefully designed knowledge
  - Contains explicit causal explanations
  - Includes rare and outlier cases
  - High transparency