Clinical decision support in practice – HL7 standards, interoperability, and selected applications

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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

Based on our estimate, medical error is the 3rd most common cause of death in the US.

All causes: 2,597k

- Cancer: 585k
- Medical error: 251k
- COPD: 149k
- Suicide: 41k
- Firearms: 34k
- Heart disease: 611k
- Motor vehicles: 34k

However, we’re not even counting this - medical error is not recorded on US death certificates.

Data source: http://www.cdc.gov/nchs/data/nvsr/nvsr64/nvsr64_02.pdf

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Model for reducing patient harm

**Individual responsibilities**

- Knowledge of remedies
- Skill to intercept harm

- Clinical skill
- Sound judgment

- Error awareness
- Calling for help

**System responsibilities**

1. Make errors more visible
   - Institute safety triggers to alert staff
   - Facilitate a culture of speaking up

2. Respond to error (rescue)
   - Make remedies available
   - Support clinician needs

3. Make errors less frequent
   - Foster culture of safety
   - Engineer hard stops for prevention

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Clinical decision support with knowledge engines

**DIAGNOSIS**
- alerts, reminders, to-do lists
- clinical test interpretations and temporal abstraction
- (tele)monitoring of chronic conditions
- differential diagnostics
  - rare diseases, rare syndromes
  - further diagnostic procedures
  - multi-morbidity
- genetics, proteomics
  - molecular variations

**PROGNOSIS**
- illness severity scores, prediction rules
- trend detection and visualization

**THERAPY**
- drug alerts, reminders, calculations
  - indication, contraindications, redundant medications, cost-effective substitutions
  - dosage calculations, drug-drug and gene-drug interactions
  - adverse drug events
- management of antimicrobial therapies
  - susceptibility and resistance rates
- pharmacogenomics

**HOSPITAL MANAGEMENT**
- computerized evidence-based workflows, clinical guidelines, protocols, SOPs
- surveillance criteria and quality benchmarking

Knowledge engines
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
  - CDS
    - deduction
      - axiomatic
IBM Watson Health vs. Medexter Health knowledge

- **raw data**
  - machine learning
  - document data

**cognitive engine**
- implicit
  - based on associations
  - empirical cases
  - partially transparent

**knowledge engine**
- explicit
  - based on relationships
  - common, rare, and “impossible” events
  - transparent

- designed knowledge
  - causal knowledge
  - machine learning results

- structured knowledge
- processing engine
**How it works**

**Use it**
- as part of your EMR
- or
- as stand-alone application

**Medical Knowledge**
- medical logic modules

**Processing Engine**

**The knowledge engine**
- In the future, any clinical activity will be either supported with or substituted by clinical knowledge engines.

**The knowledge**
- clinically proven knowledge: rules, tables, decision trees, guidelines, scores, algorithms, ...
- application-ready, evidence-based knowledge packages
- customized knowledge design or knowledge through machine learning

**The engine**
- HL7’s Arden Syntax clinical knowledge representation and processing, with fuzzy methodologies
- scalable from cloud-based servers to smartphone apps
Use Case: Hypoglycemia

DATA:
LET glucose BE READ {…glucose…};
LET physician_DECT BE DESTINATION {sms:26789};

LOGIC:
IF LATEST glucose IS LESS THAN 50 THEN
   CONCLUDE true;
ENDIF;

ACTION:
WRITE „Warning…“ AT physician_DECT;

CONCLUDE TRUE
→ Do something
Hypoglycemia alert via DECT cordless telecommunications

Event monitors are

“tireless observers, constantly monitoring clinical events”

George Hripcsak

by Stefan Kraus
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>
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<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.
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
**HEMATOLOGICAL PROFILE**

<table>
<thead>
<tr>
<th>Date</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
<th>Value 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>04-18-2015</td>
<td>19.4 /nl</td>
<td>20.1 /nl</td>
<td>17.5 /nl</td>
<td>17.1 /nl</td>
</tr>
</tbody>
</table>

**BIOCHEMICAL PROFILE**

<table>
<thead>
<tr>
<th>Date</th>
<th>Value 1</th>
<th>Value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>04-18-2015</td>
<td>169 mg/l</td>
<td>105 mg/l</td>
</tr>
</tbody>
</table>

**Inflammation markers**

<table>
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<tr>
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<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
<th>Value 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>04-18-2015</td>
<td>169 mg/l</td>
<td>105 mg/l</td>
<td>98 mg/l</td>
<td>80 mg/l</td>
</tr>
</tbody>
</table>

**Clinical Alerts**

- **04-18-2015 13:02**: Further increase of CRP
  - Persistent leukocytosis (19.4 /nl, 04-18-2015 13:02) compared to previous findings

- **04-17-2015 12:32**: Further increase of leukocytes

- **08-15-2015 13:37**: Leukocyte value indicates leukocytosis

- **04-15-2015 13:37**: Moderately increased CRP
To summarize

- Arden Syntax software: versatile, scalable, data- and knowledge-processing software for CDS and quality measures; Fuzzy Arden Syntax for linguistic and propositional uncertainty
- High integratability through web services and database connectors
- Cockpit monitoring of and dashboard analytics for adverse events
- Reporting and quality benchmarking of adverse events
- **Users**: patient-care institutions; healthcare, research, and teaching institutions; health IT companies; and consumers
Challenges to clinical decision support

• mental
  – necessity or imperative not recognized (fatalistic attitude towards risk/suffering)
  – factual incomprehension (don’t understand it)
  – emotional refusal (don’t want it)
  – insufficient endorsement (don’t do it)

• clinical
  – too simplistic or insufficient quality (lack of content quality)
  – lack in workflow integration (lack of process quality)

• technical
  – lack in structured patient data (documentation)
  – insufficient data/semantic interoperability (data and terminology standards)

• financial
  – insufficient funds (often not true!)

⇒ How to overcome these barriers? By clinically useful solutions.