Computerized data management in the ICU.

PREDICTIVE MODELING, TIME SERIES ANALYSIS AND OPPORTUNITIES FOR SUPPORT OF CARE.

Geert Meyfroidt
SIZ award 2011
Intensive care unit: data rich environment!

DATA: +/- 250 categories.

INFORMATION

KNOWLEDGE: +/- 7 variables

WISDOM

Miller G: The magical number seven plus or minus two. Psychol review, 1956
Patient data management system

- “Reporting”
  - Monitors
  - Lab
  - Devices (MV, RRT, ...)
  - Observations
  - ....
- Prescription: CPOE
- Decision support

Van Bemmel JH, Musen MA, Handbook of Medical Informatics, 2002
Computerized data management

Predictive modeling

1. Proof of concept
2. Cardiac surgery: ICU discharge

Support of care

1. Variability and glycemic control
2. Impact of an alert on tight glycemic control
Predictive modeling

Observations

Admission: demographics, medical history, admission diagnosis, ...
Observations, lab, medication. ...
Devices: monitor, ventilator, renal replacement therapy, ...

Generalization “MODEL”

“Learning”

Outcome

PDMS

94%

6%
Predictive modeling
Data mining and machine learning

- Automatic learning
- Incorporation of background knowledge
- Examples
  - Weather forecasts
  - Fraudulent bank transactions
  - IBM Watson project
  - Genome studies
  - ...
Machine learning and ICU predictions: proof of concept

Predictive tasks:
1. ICU mortality
2. ICU LOS > 3 days
3. Development of renal failure
4. Recovery from renal failure

1548 patients
- Admission data
- “Once daily” data

### Machine learning and ICU predictions: proof of concept

<table>
<thead>
<tr>
<th>Task</th>
<th>Day</th>
<th>DT</th>
<th>RF</th>
<th>NB</th>
<th>TAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality</td>
<td>Admission</td>
<td>0.79</td>
<td>0.82</td>
<td>0.88</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>ICU LOS &gt; 3 d</td>
<td>admission: 0.75</td>
<td>0.79</td>
<td>0.83</td>
<td>0.83</td>
</tr>
<tr>
<td>Renal failure: development</td>
<td>n-2</td>
<td>0.82</td>
<td>0.86</td>
<td>0.86</td>
<td>0.88</td>
</tr>
<tr>
<td></td>
<td>n-3</td>
<td>0.84</td>
<td>0.87</td>
<td>0.87</td>
<td>0.88</td>
</tr>
<tr>
<td></td>
<td>n-4</td>
<td>0.83</td>
<td>0.88</td>
<td>0.87</td>
<td>0.87</td>
</tr>
<tr>
<td>Renal failure: recovery</td>
<td>n-1</td>
<td>0.82</td>
<td>0.87</td>
<td>0.80</td>
<td>0.85</td>
</tr>
<tr>
<td></td>
<td>n-2</td>
<td>0.80</td>
<td>0.84</td>
<td>0.78</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td>n-3</td>
<td>0.80</td>
<td>0.85</td>
<td>0.80</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td>n-4</td>
<td>0.81</td>
<td>0.86</td>
<td>0.81</td>
<td>0.87</td>
</tr>
</tbody>
</table>

(aROC > 0.80)

(10-fold cross validation)

Predicting ICU length of stay after cardiac surgery

1. Probability of discharge on the day after surgery

2. Prediction of the day of discharge

- Day 1
- Day 2
- Day 3
- Day ....
Predicting ICU length of stay after cardiac surgery

Probability of discharge on the day after surgery?

<table>
<thead>
<tr>
<th></th>
<th>aROC</th>
<th>Brier Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaussian Processes (n=499)</td>
<td>&gt;0.75</td>
<td>&lt;0.25</td>
</tr>
<tr>
<td>EuroSCORE (n=499)</td>
<td>0.726</td>
<td>0.324 S</td>
</tr>
<tr>
<td>Nurse (6 u) (n=396)</td>
<td>0.695</td>
<td>0.245 S</td>
</tr>
<tr>
<td>Physician (6 u) (n=159)</td>
<td>0.758</td>
<td>0.216 S</td>
</tr>
</tbody>
</table>

BS= Mean \( [p_n - o_n]^2 \)
## Predicting ICU length of stay after cardiac surgery

### Prediction of the day of discharge?

<table>
<thead>
<tr>
<th></th>
<th>LPF</th>
<th>LPF=0</th>
<th>RMSRE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaussian Processes (n=499)</td>
<td>0 (0 - 0.4)</td>
<td>40%</td>
<td>0.408</td>
</tr>
<tr>
<td>EuroSCORE (n=499)</td>
<td>-0.3 (-0.5 - 0)</td>
<td>S</td>
<td>19%</td>
</tr>
<tr>
<td>Nurse (6 u) (n=396)</td>
<td>0 (0 - 0.3)</td>
<td>S</td>
<td>38%</td>
</tr>
<tr>
<td>Physician (6 u) (n=159)</td>
<td>0.2 (0-0.4)</td>
<td>S</td>
<td>31%</td>
</tr>
</tbody>
</table>

\[
LPF = \frac{D_{actual} - D_{predicted}}{D_{actual}}
\]
Predicting ICU length of stay after cardiac surgery: conclusion

- Computer predicts better than Euroscore, and more reliably than clinician
- Models are not universally applicable but can be ‘relearned’ in a different clinical context.
Elevated blood sugar levels are associated with increased mortality

Normalization of glycemia with intensive insulin therapy reduces ICU mortality in certain clinical settings.

Van den Berghe et al. NEJM 2001
Van den Berghe et al. NEJM 2006
Vlasselaers et al. Lancet 2009
NICE-SUGAR study, NEJM 2009
Tight glycemic control

Increased blood glucose amplitude variability (BGAV) is associated with mortality.

Egi et al, Anesthesiology 2006
Wintergerst et al, Pediatrics 2006
Krinsley et al, Crit Care Med 2008

Mean blood glucose 107 mg/dl

Hyperglycemia-induced oxidative stress?
Tight glycemic control: level and/or variability?

MICU+SICU: n=2748
- level: - mean morning
- hypo
- BGAV: - mean daily ∆ BG

Meyfroidt G et al. Crit Care Medicine 2010
Tight glycemic control: level and/or variability?

MICU: n=1200
- level: - HGI
- HoGI
- BGAV: - SD BG
- pattern: - ApEn

Van den Berghe et al, NEJM 2006
Meyfroidt G et al. Crit Care Medicine 2010
### Tight glycemic control: level and/or variability?

<table>
<thead>
<tr>
<th></th>
<th>Conventioneel</th>
<th>Intensief</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean morning BG</td>
<td>151 (27)</td>
<td>104 (23)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Hypoglycemie</td>
<td>2%</td>
<td>11%</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Mean daily △ BG</td>
<td>59 (38-90)</td>
<td>72 (52-97)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>HGI</td>
<td>58 (36-74)</td>
<td>14 (9-22)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>HoGI</td>
<td>0.09 (0.00-0.36)</td>
<td>0.90 (0.34-1.5)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>SD BG</td>
<td>38 (29-50)</td>
<td>36 (29-49)</td>
<td>0.161</td>
</tr>
<tr>
<td>ApEn</td>
<td>1.7 (0.3)</td>
<td>1.6 (0.3)</td>
<td>0.126</td>
</tr>
</tbody>
</table>

Meyfroidt G et al. Crit Care Medicine 2010
Tight glycemic control: impact of a computer alert

- IIT in Leuven
  - By nurses
  - Paper guideline (intranet)
    - Incomplete
    - Partially procedural/declarative
    - Informal

‘Intuitive decision making’
No strict ‘if-then’ protocol

Meyfroidt G et al, Intensive Care Medicine 2011
Tight glycemic control: impact of a computer alert

- **BG > 180 mg/dl**: Patient can eat
- **BG > 110 mg/dl**
  - IV- and/or enteral nutrition
- **BG 60-80 mg/dl**
- **BG 40-60 mg/dl**
- **BG < 40 mg/dl**

**Adapt insulin. New BG control in 1u**
Tight glycemic control: impact of a computer alert

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Blood glucose level</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean BG</td>
<td>112</td>
<td>110</td>
<td>0.002</td>
</tr>
<tr>
<td>HGI</td>
<td>10</td>
<td>9</td>
<td>0.004</td>
</tr>
<tr>
<td># BG values &gt;110</td>
<td>33%</td>
<td>30%</td>
<td>0.008</td>
</tr>
<tr>
<td># BG values &lt; 80</td>
<td>6%</td>
<td>6%</td>
<td>0.845</td>
</tr>
<tr>
<td># pat. with hypo &lt; 40</td>
<td>6.5%</td>
<td>4%</td>
<td>0.043</td>
</tr>
<tr>
<td><strong>BGAV</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD BG</td>
<td>28</td>
<td>28</td>
<td>0.566</td>
</tr>
<tr>
<td><strong>BG monitoring</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># measurements/pt/d</td>
<td>7.7</td>
<td>7.7</td>
<td>0.891</td>
</tr>
</tbody>
</table>

Meyfroidt G et al, Intensive Care Medicine 2011
Computerized data management in the ICU

Conclusions
Conclusions

- Advanced data analysis with automatically learning methods allows for the construction of customized clinically relevant predictive models.
- BGAV is an important feature that should be assessed when comparing blood glucose control strategies.
- Even a simple computer alert is able to have a significant impact on the quality of tight glycemic control.
Present and future research

- ICU capacity planner for cardiac surgery
- Early warning alert for elevated ICP events in brain injured patients
- Prediction of bad outcome after brain injury
- Early warning alert for AKI
- Prediction of pharmacokinetics
- Time series summary statistics: morphological clustering
- Text mining: clinical notes
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- SIZ