Big Data in Postoperative Monitoring – What's Changing?

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Disclosures

• Medtronic
• Edwards Lifesciences
• FAER “A randomized pilot trial of continuous postoperative hemodynamic and saturation monitoring”
The intraoperative period has become safer...

The postoperative period ...(not yet)?

- Death due to diseases of the heart (CDC)
- Death due to malignant neoplasms (CDC)
- Death within 30 days of admission for surgery (NIS)
- Death due to cerebrovascular diseases (CDC)
Postoperative complications occur on the general care floor

- Ward hypotension and hypoxemia
  - Common, profound, and prolonged
  - Cannot be reliably predicted
- Acute respiratory events
  - In-hospital mortality of approximately 40%
- Heart attacks occur postoperatively
  - 94% within two days
  - 50% of deaths during initial hospitalization

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Postoperative hypoxemia

Minutes hypoxemia per hour
Blinded ward monitoring

≈850 non-cardiac surgical patients

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Postoperative hypoxemia – common, undetected & difficult to predict (STOP-BANG scores)

Khanna AK, et al. BJA 2016

Postoperative hypoxemia – common, undetected & difficult to predict (long vs short acting opioids)

The heart is not too far away from the lungs…

- etCO2
- RR
- SpO2
- HR
- ? Blood Pressure

Postoperative Hypotension Matters!!

Sessler DI, et al. (POISE-2) Anesthesiology
Postoperative Hypotension Matters!!

Khanna AK et al. (Unpublished data)

Postoperative Hypotension & adverse events

<table>
<thead>
<tr>
<th>Adverse event</th>
<th>Overall</th>
<th>MAP&lt;65</th>
<th>MAP&lt;70</th>
<th>MAP&lt;75</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-day mortality</td>
<td>67,991</td>
<td>1,548 (2.3%)</td>
<td>2,312</td>
<td>18,074 (10.6%)</td>
</tr>
<tr>
<td>30-day mortality</td>
<td>67,908</td>
<td>584 (0.9%)</td>
<td>2,611</td>
<td>18,108 (10.8%)</td>
</tr>
<tr>
<td>60-day mortality</td>
<td>67,968</td>
<td>1,048 (1.6%)</td>
<td>2,611</td>
<td>15,308 (9.3%)</td>
</tr>
<tr>
<td>AAR</td>
<td>67,317</td>
<td>23 (0.3%)</td>
<td>2,732</td>
<td>12,119 (7.5%)</td>
</tr>
<tr>
<td>ARS (SIR)</td>
<td>67,300</td>
<td>92 (0.6%)</td>
<td>3,351</td>
<td>11,178 (6.7%)</td>
</tr>
<tr>
<td>7-day ARS</td>
<td>67,343</td>
<td>665 (1.0%)</td>
<td>2,808</td>
<td>18,144 (10.4%)</td>
</tr>
<tr>
<td>30-day readmissions</td>
<td>67,586</td>
<td>621 (0.9%)</td>
<td>2,207</td>
<td>15,253 (9.0%)</td>
</tr>
</tbody>
</table>
The ‘4am phenomenon’…

What (really) happens prior to a “CODE BLUE”?

What’s changing?
How about monitoring?

- 60% patients had at least one abnormal vital sign 1–4 hours before cardiorespiratory arrest
- Step-wise increase in mortality with increasing number of abnormal vital signs

Better (smarter) monitoring may be an answer?

- 97% preventable – better monitoring and response
- 42% - 2hr of last check
- Multiple prescribers
- Non-opioid sedatives
Monitoring and survival

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>ICU</th>
<th>Monitored Ward</th>
<th>Unmonitored Ward</th>
<th>P-Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of hospitals</td>
<td>445</td>
<td>445</td>
<td>445</td>
<td>445</td>
<td></td>
</tr>
<tr>
<td>Unadjusted event rate, mean (SD)</td>
<td>0.580 (0.325)</td>
<td>0.337 (0.215)</td>
<td>0.109 (0.079)</td>
<td>0.134 (0.098)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Unadjusted survival rate, mean (SD)</td>
<td>0.173 (0.079)</td>
<td>0.162 (0.096)</td>
<td>0.231 (0.171)</td>
<td>0.141 (0.122)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Adjusted survival rate, mean (SD)</td>
<td>0.144 (0.032)</td>
<td>0.140 (0.037)</td>
<td>0.153 (0.074)</td>
<td>0.106 (0.037)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Perman, et al. JAHA 2016

The ‘4am’ phenomenon

Khanna AK et al. Crit Care 2019
Continuous (smarter) monitoring for all?

- Better monitoring?
- Who to monitor?
- What to monitor?
- How to monitor?
- Data reliability/validation?
- **Alarm fatigue**
- Convert GCF -> ICU?

- Terabytes of data
- Handling alarms
- Prediction of risk

### Alarm Fatigue – and the case for AI based Optimization

> 700k+ hours of patient data

<table>
<thead>
<tr>
<th>Delay</th>
<th>81</th>
<th>83</th>
<th>85</th>
<th>87</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.88</td>
<td>1.60</td>
<td>3.54</td>
<td>8.42</td>
</tr>
<tr>
<td>60</td>
<td>0.44</td>
<td>0.87</td>
<td>1.96</td>
<td>4.74</td>
</tr>
<tr>
<td>90</td>
<td>0.29</td>
<td>0.56</td>
<td>3.31</td>
<td>3.36</td>
</tr>
<tr>
<td>120</td>
<td>0.18</td>
<td>0.41</td>
<td>1.00</td>
<td>2.59</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Alarms/Patient/Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>SpO2</td>
<td>1.17</td>
</tr>
<tr>
<td>Cardiac Rate</td>
<td>0.31</td>
</tr>
<tr>
<td>Resp Rate</td>
<td>0.87</td>
</tr>
<tr>
<td>Continuous BP</td>
<td>0.67</td>
</tr>
<tr>
<td>TOTAL</td>
<td>3.04</td>
</tr>
</tbody>
</table>

Optimize
Postoperative Hypotension – common & undetected

Spot checks missed about 50% of episodes of MAP<65mmHg detected by continuous monitoring

Turan A, Khanna AK et al. Anesthesiology 2019

Postoperative Hypertension – common & undetected

Spot checks missed about 75% of episodes of MAP>110mmHg detected by continuous monitoring

Turan A, Khanna AK et al. Anesthesiology 2019
Can we predict risk of respiratory depression?
# PRODIGY Model Derivation – Multivariate Predictors

**Clinical Characteristic** | **Estimate** | **Standard Error** | **OR** | **Pr > |t|** | **Points if Clinical Characteristic = ‘Yes’**
--- | --- | --- | --- | --- | ---
AGE (<60) | ref | - | - | - | 0
AGE (≥60 - <70) | 0.797 | 0.145 | 2.218 | <.001 | 8
AGE (≥70 - <80) | 1.237 | 0.180 | 3.445 | <.001 | 12
AGE (≥80) | 1.552 | 0.363 | 4.719 | <.001 | 16
Sex (M) | 0.772 | 0.128 | 2.163 | <.001 | 8
Opioid Naïve | 0.290 | 0.165 | 1.337 | .079 | 3
Sleep Disorders | 0.461 | 0.199 | 1.585 | .021 | 5
Heart Failure | 0.735 | 0.401 | 2.085 | .067 | 7

Sum = PRODIGY Score

619 patients with **at least one RD episode (44.8%)**

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**PRODIGY Model Derivation – Multivariate Predictors**

| **PRODIGY Score** | **Low Risk** | **Intermediate Risk** | **High Risk** | **p value**
--- | --- | --- | --- | ---
Pts in Risk Category | <8 points | 8 – 14 points | ≥15 points | 
Pts with RD in Risk Category | 359 | 474 | 471 | 
% Pts with RD in Risk Category | 23% | 41% | 64% | <.001
Sensitivity | --- | 0.85 | 0.52 | 
Specificity | --- | 0.38 | 0.76 | 

**OR (95% CI, P value)**

- OR$_{IL}$ = 2.29 (1.69–3.11, P<.001)
- OR$_{HI}$ = 5.74 (4.22–7.82, P<.001)
- OR$_{H}$ = 2.5 (1.99–3.26, P<.001)

619 patients with **at least one RD episode (44.8%)**
PRODIGY Model Accuracy

ROC Curve for GLIMMIX model
Area Under the Curve is 0.7107

Calibration Plot by Deciles
Linear Fit

*Statistical significance may be linked to other medical characteristics

All about pattern detection!

J-L Vincent, et al. EJA 2018
All about pattern detection!
The (big data) challenge... Role for AI
Difficult to predict
Smart monitoring
Continuous monitoring

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Scoring systems
Proactive RRT
Alarm fatigue & artifact
Central platforms & AI
Culture change
Several ‘critical big data points’ at home?
Continuous smarter parenting!

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