Smart Strategies In Medical Emergency Teams: A clinical perspective

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Disclosures

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  – National Heart Lung Blood Institute
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• Ownership interests:
  – QuantHC
    • Intellectual property over the algorithms described
    • Patent pending, ARCD.P0535US.P2
Hospitalization Time Course

Healthy

Admitted

Physiologic State

Dead

Time

ICU Transfer

Rapid Response Team

Cardiac arrest
Three step model to improving outcomes

1. Recognition
2. Call for help
3. Treatment
Recognition and activation are not physiologic
Adjusting to subtle changes in physiology
Automating recognition and activation
Traditional MET activation criteria

**Airway**
If threatened

**Breathing**
All respiratory arrests
Respiratory rate < 5 breaths per min
Respiratory rate > 36 breaths per min

**Circulation**
All cardiac arrests
Pulse rate < 40 beats per min
Pulse rate > 140 beats per min
Systolic blood pressure < 90 mm Hg

**Neurology**
Sudden fall in level of consciousness
(fall in Glasgow coma scale of > 2 points)
Repeated or extended seizures

**Other**
Any patient you are seriously worried about that does not fit the above criteria

Cardiac arrest AUC: 0.63
## Modified Early Warning Score (MEWS)

Subbe, QJM, 2001

### Cardiac arrest AUC: 0.76

<table>
<thead>
<tr>
<th></th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory rate (RPM)</td>
<td>—</td>
<td>≤ 8</td>
<td>—</td>
<td>9-14</td>
<td>15-20</td>
<td>21-29</td>
<td>≥ 30</td>
</tr>
<tr>
<td>Heart rate (BPM)</td>
<td>—</td>
<td>≤ 40</td>
<td>41-50</td>
<td>51-100</td>
<td>101-110</td>
<td>111-129</td>
<td>≥ 130</td>
</tr>
<tr>
<td>Systolic BP</td>
<td>≤ 70</td>
<td>71-80</td>
<td>81-100</td>
<td>101-199</td>
<td></td>
<td></td>
<td>≥ 200</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>—</td>
<td>≤ 35</td>
<td>—</td>
<td>35.0-38.4</td>
<td>—</td>
<td>&gt;38.5</td>
<td>—</td>
</tr>
<tr>
<td>AVPU</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Alert</td>
<td>React to Voice</td>
<td>React to Pain</td>
<td>Unresp</td>
</tr>
</tbody>
</table>
Paper-based EWS scoring
Leveraging electronic data
Deriving a computer-based early warning score

• Data set:
  – Over 58,000 admissions
  – 109 cardiac arrests on the ward
  – 2,543 ICU transfers

• Methods:
  – Multinomial logistic regression
  – Competing risk model
  – Longitudinal analysis
  – Normal imputation

Churpek, CCM, 2014
## eCART model for cardiac arrest

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (hr)</td>
<td>0.00</td>
</tr>
<tr>
<td>Prior ICU stay (1 = Yes, 0 = No)</td>
<td>1.37</td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
<td>0.03</td>
</tr>
<tr>
<td>Diastolic blood pressure (mm Hg)</td>
<td>-0.02</td>
</tr>
<tr>
<td>Respiratory rate (breaths/min)</td>
<td>0.14</td>
</tr>
<tr>
<td>Oxygen saturation (%)</td>
<td>0.07</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>-0.31</td>
</tr>
<tr>
<td>Mental status (alert, responsive to voice, responsive to pain, unresponsive)</td>
<td>0.43</td>
</tr>
<tr>
<td>On room air (1 = Yes, 0 = No)</td>
<td>-0.64</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>0.03</td>
</tr>
<tr>
<td>Blood urea nitrogen (mg/dL)</td>
<td>0.01</td>
</tr>
<tr>
<td>Anion gap (mEq/L)</td>
<td>0.13</td>
</tr>
<tr>
<td>Hemoglobin (g/dL)</td>
<td>-0.17</td>
</tr>
<tr>
<td>Platelet count (K/µL)</td>
<td>-0.002</td>
</tr>
<tr>
<td>Potassium (mEq/L)</td>
<td>0.17</td>
</tr>
<tr>
<td>WBC count (K/µL)</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Cardiac arrest AUC: 0.88
Risk score change over time

- Cardiac arrest score
- ICU transfer score
- Control score

Time preceding event (hours):
-48 - 0
Risk Stratification using eCART

- Top 5% sickest patients
- Next 10%
Real-time implementation

Vital Signs
125 bpm
98% O₂
120/80

Lab Values
Hemoglobin Alert
Potassium

Demographics
65 yo
ICU transfer

F(x)=...
eCART
Silent phase comparison to standard care

Cardiac Arrest
[n=10]

ICU Transfer
[n=383]

Percent of Events Captured

- RRT Called
- eCART (High/Mod Risk)
Threshold Timing for ICU Transfers

- eCART (High Risk) Median: 32.9 hours
- RRT median: 1.7 hours

Δ 31 hours (p<0.0001)
Mortality increases linearly with ICU transfer delay
In-Hospital Mortality by ICU transfer delay

- < 6 hrs: 25%
- > 6 hrs: 33%

$p<0.001$
Length of Stay by ICU transfer delay

$p < 0.001$

- **< 6 hrs**: 11 Days
- **> 6 hrs**: 13 Days
Real-Time Patient Dashboard

<table>
<thead>
<tr>
<th>Name</th>
<th>MRN</th>
<th>Age</th>
<th>Sex</th>
<th>Room</th>
<th>Risk</th>
<th>Trend</th>
<th>Last Updated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Johnson, R</td>
<td>3297845295</td>
<td>64</td>
<td>M</td>
<td>784</td>
<td>High</td>
<td></td>
<td>17-Apr-2015 13:32:01</td>
</tr>
<tr>
<td>Wilson, C</td>
<td>1298495234</td>
<td>72</td>
<td>M</td>
<td>849</td>
<td>High</td>
<td></td>
<td>17-Apr-2015 13:37:54</td>
</tr>
<tr>
<td>Brown, W</td>
<td>3759274021</td>
<td>45</td>
<td>M</td>
<td>927</td>
<td>Moderate</td>
<td></td>
<td>17-Apr-2015 13:34:36</td>
</tr>
<tr>
<td>Jackson, T</td>
<td>1485945453</td>
<td>60</td>
<td>F</td>
<td>594</td>
<td>Moderate</td>
<td></td>
<td>17-Apr-2015 13:40:44</td>
</tr>
<tr>
<td>Miller, D</td>
<td>5234656234</td>
<td>73</td>
<td>M</td>
<td>465</td>
<td>Normal</td>
<td></td>
<td>17-Apr-2015 12:42:09</td>
</tr>
<tr>
<td>Thompson, D</td>
<td>2342366948</td>
<td>52</td>
<td>F</td>
<td>236</td>
<td>Normal</td>
<td></td>
<td>17-Apr-2015 13:07:12</td>
</tr>
</tbody>
</table>
Real-Time Risk Trend

Early Warning - Patient Trend

Name: Smith, C
MRN: 3852015762
Age: 66
Sex: M
Room: 620

Score: 59
Date: 17-Apr-2015 08:28
Prior ICU: No
Temperature: 35.1°C
Heart Rate: 130 bpm
Systolic BP: 70
Respiratory Rate: 22 rpm
O2 Saturation: 97%
Mental Status: Alert
Potassium: 5.3 mEq/L
BUN: 27 mg/dL
Anion Gap: 14 mEq/L
WBC: 8.2
Hemoglobin: 9.9 g/dL
Platelets: 187
Age: 66
Suppl O2: Yes

24 Hours
48 Hours
All data

eCART simplifying medicine
powered by apervita
Garbage in… Tweaking future inputs

Respiratory rate

Mental status

Clinical judgment
MENTAL STATUS:
WHAT ARE THE OPTIONS?
AVPU scale

- A: The patient is awake.
- V: The patient responds to verbal stimulation.
- P: The patient responds to painful stimulation.
- U: The patient is completely unresponsive.
# Glasgow Coma Scale

<table>
<thead>
<tr>
<th>Response</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Eye opening</strong></td>
<td></td>
</tr>
<tr>
<td>Opens eyes spontaneously</td>
<td>4</td>
</tr>
<tr>
<td>Opens eyes in response to speech</td>
<td>3</td>
</tr>
<tr>
<td>Open eyes in response to painful stimulation (eg, endotracheal suctioning)</td>
<td>2</td>
</tr>
<tr>
<td>Does not open eyes in response to any stimulation</td>
<td>1</td>
</tr>
<tr>
<td><strong>Motor response</strong></td>
<td></td>
</tr>
<tr>
<td>Follows commands</td>
<td>6</td>
</tr>
<tr>
<td>Makes localized movement in response to painful stimulation</td>
<td>5</td>
</tr>
<tr>
<td>Makes nonpurposeful movement in response to noxious stimulation</td>
<td>4</td>
</tr>
<tr>
<td>Flexes upper extremities/extends lower extremities in response to pain</td>
<td>3</td>
</tr>
<tr>
<td>Extends all extremities in response to pain</td>
<td>2</td>
</tr>
<tr>
<td>Makes no response to noxious stimuli</td>
<td>1</td>
</tr>
<tr>
<td><strong>Verbal response</strong></td>
<td></td>
</tr>
<tr>
<td>Is oriented to person, place, and time</td>
<td>5</td>
</tr>
<tr>
<td>Converses, may be confused</td>
<td>4</td>
</tr>
<tr>
<td>Replies with inappropriate words</td>
<td>3</td>
</tr>
<tr>
<td>Makes incomprehensible sounds</td>
<td>2</td>
</tr>
<tr>
<td>Makes no response</td>
<td>1</td>
</tr>
</tbody>
</table>
Richmond Agitation Sedation Scale (RASS)

<table>
<thead>
<tr>
<th>Score</th>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>+4</td>
<td>Combative</td>
<td>Overtly combative, violent, immediate danger to staff</td>
</tr>
<tr>
<td>+3</td>
<td>Very agitated</td>
<td>Pulls or removes tube(s) or catheter(s); aggressive</td>
</tr>
<tr>
<td>+2</td>
<td>Agitated</td>
<td>Frequent non-purposeful movement, fights ventilator</td>
</tr>
<tr>
<td>+1</td>
<td>Restless</td>
<td>Anxious but movements not aggressive vigorous</td>
</tr>
<tr>
<td>0</td>
<td>Alert and calm</td>
<td></td>
</tr>
<tr>
<td>-1</td>
<td>Drowsy</td>
<td>Not fully alert, but has sustained awakening (eye-opening/eye contact) to voice (&gt;10 seconds)</td>
</tr>
<tr>
<td>-2</td>
<td>Light sedation</td>
<td>Briefly awakens with eye contact to voice (&lt;10 seconds)</td>
</tr>
<tr>
<td>-3</td>
<td>Moderate sedation</td>
<td>Movement or eye opening to voice (but no eye contact)</td>
</tr>
<tr>
<td>-4</td>
<td>Deep sedation</td>
<td>No response to voice, but movement or eye opening to physical stimulation</td>
</tr>
<tr>
<td>-5</td>
<td>Unarousable</td>
<td>No response to voice or physical stimulation</td>
</tr>
</tbody>
</table>
Comparison of Mental-Status Scales for Predicting Mortality on the General Wards

Frank J. Zadraecz, MPH¹, Linda Tien, MD², Brian J. Robertson-Dick, MD³, Trevor C. Yuen, MS¹, Nicole M. Twu, MS¹,
Matthew M. Churpek, MD, MPH, PhD⁴, Dana P. Edelson, MD, MS¹*

<table>
<thead>
<tr>
<th>Scale</th>
<th>AUC (95%CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined GCS and RASS</td>
<td>0.85 (0.82-0.87)</td>
</tr>
<tr>
<td>RASS</td>
<td>0.82 (0.79-0.84)</td>
</tr>
<tr>
<td>GCS Total</td>
<td>0.80 (0.77-0.83)</td>
</tr>
<tr>
<td>GCS Verbal</td>
<td>0.78 (0.75-0.81)</td>
</tr>
<tr>
<td>GCS Motor</td>
<td>0.78 (0.75-0.81)</td>
</tr>
<tr>
<td>GCS Eye (AVPU)</td>
<td>0.73 (0.71-0.76)</td>
</tr>
</tbody>
</table>

Area Under the Receiver Operating Characteristic Curve (AUC)
RESPIRATORY RATE: THE MISSING VITAL SIGN
Variable importance

- Respiratory rate: 100
- Heart rate: 77
- Age: 66
- Systolic blood pressure: 63
- Diastolic blood pressure: 51
- Pulse pressure index: 48
- Temperature: 43
- Blood urea nitrogen: 41
- White blood cell count: 40
- Glucose: 38
Respiratory rate is poorly recorded

Semier, Chest 2013
“RR” vs RR: which one is more predictive?
QUANTIFYING CLINICAL JUDGEMENT
Introduction of PAR
The Patient Acuity Rating

• How likely is this patient to suffer a cardiac arrest or require emergent transfer to the ICU in the next 24 hours?

Extremely unlikely 1 2 3
Neither likely nor unlikely 4 5 6
Extremely likely 7

Cardiac arrest or ICU transfer AUC: 0.82
### PAR sensitivities and specificities

<table>
<thead>
<tr>
<th>PAR</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>16%</td>
<td>99%</td>
</tr>
<tr>
<td>≥ 6</td>
<td>41%</td>
<td>95%</td>
</tr>
<tr>
<td>≥ 5</td>
<td>62%</td>
<td>85%</td>
</tr>
<tr>
<td>≥ 4</td>
<td>82%</td>
<td>68%</td>
</tr>
<tr>
<td>≥ 3</td>
<td>93%</td>
<td>41%</td>
</tr>
<tr>
<td>≥ 2</td>
<td>99%</td>
<td>12%</td>
</tr>
<tr>
<td>≥ 1</td>
<td>100%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Edelson, JHM, 2011
PAR vs MEWS: effect may be additive

From: The Value of Clinical Judgment in the Detection of Clinical Deterioration

RETHINKING NIGHTTIME VITALS
Waking Hospital Patients to Check Vital Signs May Do More Harm Than Good

Study suggests nearly half might benefit more from undisturbed sleep

July 1, 2013

By Dennis Thompson
HealthDay Reporter

MONDAY, July 1 (HealthDay News) -- The health and well-being of many hospital patients might improve if nurses stop performing overnight vital-sign checks on them, according to new research.

Nearly half the patients awakened for late-night vital-sign checks are extremely unlikely to suffer a medical emergency in the next 24 hours, said study author Dr. Dana Edelson, a hospitalist with the department of medicine at the University of Chicago.

If left alone and allowed to sleep, these patients likely will heal faster and have a better attitude during their hospital stay, she said.
From: A Prospective Study of Nighttime Vital Sign Monitoring Frequency and Risk of Clinical Deterioration
Example Clinical Decision Support Matrix by Acuity

- **High**
  - Automatic MET/RRT
  - Twice daily bedside rounding with Attending

- **Moderate**
  - Bedside Rounding between RN/MD
  - Proactive rounding by MET/RRT

- **Normal**
  - Standard care

- **Low**
  - No night-time vital signs
Conclusions

• Clinical deterioration on the wards is largely predictable
• Statistically derived algorithms, such as eCART, have improved accuracy over traditional MET activation criteria
• Early identification and transfer to the ICU is associated with decreased mortality and shorter length of stay
• Algorithms are likely to be strengthened by reliable input regarding respiratory rate, mental status and clinical judgment
Questions?