Should ALL Hospitalized Patients Be Continuously Monitored?

Michael A. DeVita, M.D., FACP
St. Vincent’s Medical Center
Bridgeport, CT, USA
Incidence of treated cardiac arrest in hospitalized patients in the United States*

Raina M. Merchant, MD, MS; Lin Yang, MS; Lance B. Becker, MD; Robert A. Berg, MD; Vinay Nadkarni, MD; Graham Nichol, MD, MPH; Brendan G. Carr, MD, MS; Nandita Mitra, PhD; Steven M. Bradley, MD, MPH; Benjamin S. Abella, MD, MPhil; Peter W. Groeneveld, MD, MS; the American Heart Association Get With The Guidelines-Resuscitation (GWTG-R) Investigators

Table 2. Get With the Guidelines-Resuscitation annual inhospitual cardiac arrest events and bed days (for hospitals \( n = 150 \) contributing data for all 5 yrs, 2003–2007)

<table>
<thead>
<tr>
<th>Year</th>
<th>Cardiac Arrest Events</th>
<th>Bed Days</th>
<th>Mean Event Rate (per 1000 Bed Days)</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>10,503</td>
<td>12,061,231</td>
<td>0.87</td>
<td>( p = .01 )</td>
</tr>
<tr>
<td>2004</td>
<td>11,366</td>
<td>13,076,891</td>
<td>0.87</td>
<td>( p = .01 )</td>
</tr>
<tr>
<td>2005</td>
<td>12,125</td>
<td>13,097,347</td>
<td>0.93</td>
<td>( p = .01 )</td>
</tr>
<tr>
<td>2006</td>
<td>12,478</td>
<td>13,175,655</td>
<td>0.95</td>
<td>( p = .01 )</td>
</tr>
<tr>
<td>2007</td>
<td>11,840</td>
<td>11,899,325</td>
<td>0.99</td>
<td>( p = .01 )</td>
</tr>
</tbody>
</table>

Figure 1. Annual event rate of inhospitual cardiac arrest in hospitals contributing data to the Get With the Guidelines-Resuscitation Registry for consecutive years 2003–2007. The circular points represent the event rates and the corresponding bars represent the interquartile range.
Goal of a Rapid Response System: Eliminate all preventable deaths
Prevalence of MET-criteria in a Swedish University Hospital

Bell, Konrad et al, Resuscitation

- Among 895 patients in a single hospital on two different days
  - 4.5% satisfied MET criteria!
  - Higher mortality

Figure 2. Kaplan-Meier curve stratified by patient category
CRITICAL ILLNESS IS COMMON

- IT OCCURS OUTSIDE THE ICU
- DEATH RISK IS INCREASED LONG TERM
Rapid Response System Structure

Afferent Limb

Event detection

Trigger

Urgent Un-met Patient Need

Administration oversees all functions

Data collection and analysis for Process Improvement

Data acquisition point

Efferent Limb

MET/RRT/CCO

Specialized resources

Cardiac Arrest Team

Trauma Team

Stroke Team

DeVita CCM 2006
Continued Cardiac Arrest Rate Improvement: -38%

Annual Crisis Rate UPMC Presbyterian Montefiore Hospital

Educational initiative start

DeVita 2004 Qual Safety Health Care
Survival Analysis

<table>
<thead>
<tr>
<th>Study periods</th>
<th>Number of patients</th>
<th>Death during 1500 days after admission</th>
<th>censored</th>
<th>percentage of censored</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDU</td>
<td>1115</td>
<td>381</td>
<td>734</td>
<td>65.8%</td>
</tr>
<tr>
<td>MET</td>
<td>1067</td>
<td>303</td>
<td>764</td>
<td>71.6%</td>
</tr>
</tbody>
</table>

Log-Rank Test p=0.0012

Bellomo et al. Personal communication.

Based on MJA 2003; 170: 283-7.
Delayed MET activation – Consequence

- Delayed MET activation increases death

Log Rank $P = .049$
Finding crisis patients: variability decreases as monitoring increases

Figure 4: Percent change in condition 'C' rate during day (7 a.m. to 6:59 p.m.) compared to night (7:00 p.m. to 8:59 a.m.) in unmonitored units, monitored units and ICUs (N=3330).

Galhotra, DeVita, QSHC 2007
Outcome for cardiac arrests based on setting

Least likely to survive event

Most likely to survive event

Unmonitored: n=22
Monitored: n=52
ICU: n=30

More Healthy        Less Healthy

Survived to discharge (p=.289)
Survived event, died (p=.022)
Died during event (p=.002)

Galhotra Qual Safety Healthcare 2007
How much can intermittent monitoring help?

Four Problems:
Sampling error
Compliance error
Recognition error
Prediction error
Sampling Error

Potential benefits of continuous monitoring of breathing rate

Breathing rate

- 30
- 20
- 10

EWS weighting

- 3
- 2
- 1
- 0

Time

Nurse

Continuous monitoring
A review, and performance evaluation, of single-parameter “track and trigger” systems

Gary B. Smith a,*, David R. Prytherch b, Paul E. Schmidt b, Peter I. Featherstone b, Bernie Higgins c

Table 3: The performance of 30 SPITTS using hospital mortality as the outcome

<table>
<thead>
<tr>
<th>Class</th>
<th>System evaluated</th>
<th>Triggered</th>
<th>Did not trigger</th>
<th>Total triggers, n (%)</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>PPV (%)</th>
<th>NPV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Dead on discharge n (%)</td>
<td>Alive on discharge n (%)</td>
<td>Dead on discharge n (%)</td>
<td>Alive on discharge n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Bell (standard)</td>
<td>126 (1.3)</td>
<td>437 (4.4)</td>
<td>709 (7.1)</td>
<td>8715 (87.3)</td>
<td>563 (5.6)</td>
<td>15.1</td>
<td>95.2</td>
</tr>
<tr>
<td>2</td>
<td>Bell (extended)</td>
<td>249 (2.5)</td>
<td>1202 (12.0)</td>
<td>774 (7.8)</td>
<td>8979 (89.9)</td>
<td>1451 (14.5)</td>
<td>29.8</td>
<td>86.9</td>
</tr>
<tr>
<td>3</td>
<td>Bell (restricted)</td>
<td>61 (0.6)</td>
<td>173 (1.7)</td>
<td>999 (6.0)</td>
<td>8052 (80.6)</td>
<td>1323 (13.4)</td>
<td>28.3</td>
<td>88.0</td>
</tr>
<tr>
<td>4</td>
<td>Bal</td>
<td>236 (2.4)</td>
<td>1100 (11.0)</td>
<td>967 (10.7)</td>
<td>8863 (87.0)</td>
<td>618 (6.2)</td>
<td>19.0</td>
<td>95.0</td>
</tr>
<tr>
<td>5</td>
<td>Parissopoulos</td>
<td>206 (2.1)</td>
<td>714 (7.4)</td>
<td>643 (6.4)</td>
<td>8547 (85.6)</td>
<td>779 (8.0)</td>
<td>23.0</td>
<td>93.4</td>
</tr>
<tr>
<td>6</td>
<td>Hickey</td>
<td>159 (1.6)</td>
<td>459 (4.6)</td>
<td>676 (6.8)</td>
<td>8693 (87.0)</td>
<td>618 (6.2)</td>
<td>19.0</td>
<td>95.0</td>
</tr>
<tr>
<td>7</td>
<td>Salamonson</td>
<td>192 (1.9)</td>
<td>605 (6.1)</td>
<td>564 (6.4)</td>
<td>8534 (85.5)</td>
<td>777 (8.0)</td>
<td>23.0</td>
<td>93.4</td>
</tr>
<tr>
<td>8</td>
<td>Buist</td>
<td>193 (1.9)</td>
<td>618 (6.2)</td>
<td>623 (6.2)</td>
<td>8448 (84.6)</td>
<td>916 (9.2)</td>
<td>25.4</td>
<td>92.3</td>
</tr>
<tr>
<td>9</td>
<td>Bellomo</td>
<td>212 (2.1)</td>
<td>704 (7.0)</td>
<td>612 (6.1)</td>
<td>8352 (83.6)</td>
<td>1023 (10.2)</td>
<td>26.7</td>
<td>91.3</td>
</tr>
<tr>
<td>10</td>
<td>Jones</td>
<td>223 (2.2)</td>
<td>800 (8.0)</td>
<td>635 (6.4)</td>
<td>8373 (83.8)</td>
<td>799 (9.8)</td>
<td>24.0</td>
<td>91.5</td>
</tr>
<tr>
<td>11</td>
<td>Green</td>
<td>441 (4.4)</td>
<td>2830 (28.3)</td>
<td>394 (3.9)</td>
<td>7935 (78.7)</td>
<td>562 (5.6)</td>
<td>17.4</td>
<td>95.4</td>
</tr>
<tr>
<td>12</td>
<td>Harrison (early)</td>
<td>145 (1.5)</td>
<td>417 (4.2)</td>
<td>413 (4.1)</td>
<td>8672 (86.7)</td>
<td>2850 (28.5)</td>
<td>50.5</td>
<td>73.5</td>
</tr>
<tr>
<td>13</td>
<td>Harrison (late)</td>
<td>145 (1.5)</td>
<td>417 (4.2)</td>
<td>413 (4.1)</td>
<td>8672 (86.7)</td>
<td>2850 (28.5)</td>
<td>50.5</td>
<td>73.5</td>
</tr>
<tr>
<td>14</td>
<td>Smith</td>
<td>222 (2.2)</td>
<td>800 (8.0)</td>
<td>635 (6.4)</td>
<td>8373 (83.8)</td>
<td>799 (9.8)</td>
<td>24.0</td>
<td>91.5</td>
</tr>
<tr>
<td>15</td>
<td>Lee</td>
<td>222 (2.2)</td>
<td>800 (8.0)</td>
<td>635 (6.4)</td>
<td>8373 (83.8)</td>
<td>799 (9.8)</td>
<td>24.0</td>
<td>91.5</td>
</tr>
<tr>
<td>16</td>
<td>Buist</td>
<td>379 (3.8)</td>
<td>2373 (23.8)</td>
<td>456 (4.6)</td>
<td>8579 (85.7)</td>
<td>2752 (27.6)</td>
<td>45.4</td>
<td>74.1</td>
</tr>
<tr>
<td>17</td>
<td>McGlinn</td>
<td>201 (2.0)</td>
<td>763 (7.6)</td>
<td>634 (6.3)</td>
<td>8389 (84.0)</td>
<td>964 (9.7)</td>
<td>24.1</td>
<td>91.7</td>
</tr>
<tr>
<td>18</td>
<td>de Pennington</td>
<td>182 (1.8)</td>
<td>686 (6.9)</td>
<td>634 (6.3)</td>
<td>8389 (84.0)</td>
<td>964 (9.7)</td>
<td>24.1</td>
<td>91.7</td>
</tr>
<tr>
<td>19</td>
<td>McArthur-Rousè</td>
<td>124 (1.2)</td>
<td>354 (3.6)</td>
<td>711 (7.1)</td>
<td>8788 (88.0)</td>
<td>488 (4.9)</td>
<td>14.9</td>
<td>96.0</td>
</tr>
<tr>
<td>20</td>
<td>Foraila</td>
<td>162 (1.6)</td>
<td>493 (4.9)</td>
<td>673 (6.7)</td>
<td>8659 (86.7)</td>
<td>655 (6.6)</td>
<td>19.4</td>
<td>94.6</td>
</tr>
<tr>
<td>21</td>
<td>Cloff</td>
<td>259 (2.6)</td>
<td>992 (9.9)</td>
<td>576 (5.6)</td>
<td>8100 (81.7)</td>
<td>1251 (12.5)</td>
<td>31.0</td>
<td>89.2</td>
</tr>
<tr>
<td>22</td>
<td>Holder</td>
<td>224 (2.2)</td>
<td>874 (8.8)</td>
<td>669 (6.7)</td>
<td>8630 (86.4)</td>
<td>688 (6.9)</td>
<td>19.9</td>
<td>94.3</td>
</tr>
<tr>
<td>23</td>
<td>Balistow</td>
<td>166 (1.7)</td>
<td>522 (5.2)</td>
<td>576 (5.8)</td>
<td>8160 (81.7)</td>
<td>1251 (12.5)</td>
<td>31.0</td>
<td>89.2</td>
</tr>
<tr>
<td>24</td>
<td>Bristow</td>
<td>134 (1.3)</td>
<td>413 (4.1)</td>
<td>701 (7.0)</td>
<td>8739 (87.5)</td>
<td>547 (5.5)</td>
<td>16.0</td>
<td>95.5</td>
</tr>
<tr>
<td>25</td>
<td>Hounihan</td>
<td>447 (4.7)</td>
<td>244 (0.2)</td>
<td>687 (6.9)</td>
<td>8068 (87.2)</td>
<td>501 (6.2)</td>
<td>17.7</td>
<td>94.8</td>
</tr>
<tr>
<td>26</td>
<td>Jones</td>
<td>145 (1.5)</td>
<td>466 (4.5)</td>
<td>690 (6.9)</td>
<td>8706 (87.2)</td>
<td>591 (5.9)</td>
<td>17.4</td>
<td>95.1</td>
</tr>
<tr>
<td>27</td>
<td>Subbo</td>
<td>282 (0.8)</td>
<td>297 (2.5)</td>
<td>753 (7.5)</td>
<td>8903 (89.1)</td>
<td>331 (3.3)</td>
<td>9.8</td>
<td>97.3</td>
</tr>
<tr>
<td>28</td>
<td>Jacques (late)</td>
<td>145 (1.5)</td>
<td>466 (4.5)</td>
<td>690 (6.9)</td>
<td>8706 (87.2)</td>
<td>591 (5.9)</td>
<td>17.4</td>
<td>95.1</td>
</tr>
<tr>
<td>29</td>
<td>Offner</td>
<td>233 (2.3)</td>
<td>814 (8.2)</td>
<td>602 (6.0)</td>
<td>8338 (83.5)</td>
<td>1047 (10.5)</td>
<td>27.9</td>
<td>91.1</td>
</tr>
</tbody>
</table>
The problem with trying to predict the future is:

You can’t.
Presumes that all events are predictable, and all risk is definable

Does the data support our ability to identify risk?
Why RRS are Needed

• Patients will unexpectedly and unpredictably deteriorate from time to time either due to error or disease.
• Critical illness can kill quickly, failure to act rapidly can be fatal.
• All needed resources are not always immediately available.
• A plan must exist to find and handle critical illness anywhere in the hospital, on a moment’s notice.
<table>
<thead>
<tr>
<th></th>
<th>Cases (n=88)</th>
<th>Controls (n=352)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic BP, mm Hg</td>
<td>129 (29)</td>
<td>129 (24)</td>
<td>0.86</td>
</tr>
<tr>
<td>Diastolic BP, mm Hg</td>
<td>71 (18)</td>
<td>75 (17)</td>
<td>0.04</td>
</tr>
<tr>
<td>Heart rate, min⁻¹</td>
<td>91 (19)</td>
<td>90 (21)</td>
<td>0.81</td>
</tr>
<tr>
<td>Pulse pressure index</td>
<td>0.44 (0.11)</td>
<td>0.42 (0.10)</td>
<td>0.03</td>
</tr>
<tr>
<td>Respiratory rate, min⁻¹</td>
<td>20 (3)</td>
<td>20 (3)</td>
<td>0.17</td>
</tr>
<tr>
<td>Temperature, °F</td>
<td>97.1 (1.2)</td>
<td>97.4 (1.3)</td>
<td>0.07</td>
</tr>
<tr>
<td>Oxygen Saturation, %</td>
<td>96 (8)</td>
<td>97 (3)</td>
<td>0.26</td>
</tr>
<tr>
<td>Alert mental status</td>
<td>63 (72)</td>
<td>254 (72)</td>
<td>0.92</td>
</tr>
</tbody>
</table>

Controls=Patients on same unit at time of cardiac arrest event

Predicting cardiac arrest on the wards: a nested case-control study

Matthew M. Churpek, Trevor C. Yuen, Michael T. Huber, Seo Young Park, Jesse B. Hall and Dana P. Edelson

*Chest*: Prepublished online November 3, 2011; DOI 10.1378/chest.11-1301
Phase 1 MET<sub>full</sub> patient who had Condition C called at 13:29
Just as many crisis events

Many fewer progress to severe instability

Impact of Pulse Oximetry Surveillance on Rescue Events and Intensive Care Unit Transfers

A Before-and-After Concurrence Study

Andreas H. Taenzer, M.D., F.A.A.P.,* Joshua B. Pyke, B.E.,† Susan P. McGrath, Ph.D.,‡ George T. Blika, M.D.§

Rescue Events

• RRS events decreased
  • From 3.4 to 1.2/1000 discharges.
• ICU transfers decreased
  • From 5.6 to 2.9/1000 patient days
• Control units no change

ICU Transfers

Anesthesiology 2010; 112: 282-87
What is the cost?

• Costs have never been carefully studied: universal monitoring may actually save huge cost.
  – Intra-hospital transfers: cleaning, transports, handoffs, lost treatment time around transports, transporters, monitors, bed assignment: 2 hospital days/day lost!
  – Decreased nursing time for obtaining VS and recording in EHR
  – Shorter LOS with fewer transfers
Continuous Monitoring

Cost Benefits
- Fewer ICU admissions
- Fewer deaths
- Decreased patient transfers (.5-1d/tx)
- Decreased bed turnovers
- Easier to move staff than move patient for acuity
- Potential satisfier

Cost Detriments
- Hi capital expense
- Potential to increase nursing workload
- New operating expense for disposables
- Potential nurse dissatisfaction
  - Recruitment/retention
Conclusions

- Monitoring has two possible functions:
  - Prediction: Risk of an event
  - Detection: Real time crisis identification
- Failure to continuously monitor will always result in some unpredictable crises being treated too late
- **Continuous** Monitoring is Required to Maximize potential of the RRS and prevent unexpected cardiac arrests
Special Article

Findings of the First Consensus Conference on Medical Emergency Teams®

Michael A. DeVita, MD; Rinaldo Bellomo, MD; Kenneth Hillman, MD; John Kellum, MD; Armando Rotondi, PhD; Dan Teles, MD; Andrew Auerbach, MD; Wen-Jen Chen, MD, PhD; Kathy Duncan, RN; Gary Kennard, MSc, BSc(Hons); RH; QAN/RC; Max Bell, MD; Michael Buist, MIE(BC); FRACP; FJFICM; Jack Chen, MIE(H); MD; Paul Gillett, FRACP; FRCA, MD; Ann Kirby, MD; Geoff Lighthall, MD, PhD; John O'Sullivan, MD, FCP, MHI; MM; H. Scott Braithmate, MD; John Goodacre, MD; Eric Miller, MD, MSc; Miniti Draper, MD, PhD; Luci Savitz, PhD, MBA; Liz Young, MA, COM, FAPPRP; Sanjay Gadhvi, MD

Background: Studies have estimated that physiological instability and adverse outcomes are prevalent and have been described as events in hospitalised patients. In response to these considerations, the concept of a Rapid Response System (RRS) has emerged. This rapid team is commonly known as a medical emergency team (MET), rapid response team (RRT), or critical care outreach (CCO). Studies show that an RRS may improve outcomes, but questions remain regarding the benefit, design elements, and sustainability of implementing a RRS system.

Methods: In June 2006 an International Conference on Medical Emergency Teams (ICOMET) included experts in patient safety, hospital medicine, critical care medicine, and nurses. Sessions of the conference were designed to include literature reviews, and preliminary answers to potential questions. The conference convened for 2 days to develop a consensus document. Four major content areas were addressed: What is a RRS system? In response to these considerations, the concept of a Rapid Response System (RRS) has emerged. What is a NET syndrome? What are barriers to METS? How should outcomes be measured? Panelists considered whether all hospitals should implement an RRS. Results: Patients needing a RRS intervention are suddenly critically ill and have a minimum of resources to provide. Hospitals should implement an RRS, which consists of four elements: an alert, “critical decision” and “response triggering” mechanics; an alert, predetermined rapid response team; a governance/administration structure to support and organize resources; and a mechanism to escalate critical care support and promote hospital process improvement to prevent future events. (Crit Care Med 2006; 34:2462–2478)

Introduction: medical emergency teams; rapid response teams; cardiac arrest resuscitation; process improvement; consensus panel; patient safety; critical care

The care of hospital patients is complex, a result of many more comorbidities, a significant proportion of hospital patients experience serious adverse events during their stay, including cardiac arrest, unexplained admissions to the intensive care units (ICUs), and death. Studies have estimated that many of these events are preceded by warning signs in the form of physiological instability (e.g., hypoxemia, tachycardia, hypotension, decreased oxygen saturation, and changes in conscious state) (Franklin & Mathew 1994, Harrisson et al. 2002). In theory, when abnormal physiology is identified and corrected, outcome may improve. In recent years, these considerations, the concept of the Rap"