AI Powered Early Warning System to Improve Patient Safety

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Conflict of Interest

Shelley Chang, MD, PhD & Vibin Roy, MD, MBA

Have no real or apparent conflicts of interest to report.
Agenda

Background
Early Model: Auto-EWS 1.0
Next Generation: Auto-EWS 2.0
Case Studies
Summary
Learning Objectives

• Learning Objective 1: Summarize the scope and scale of preventable hospital deaths and unplanned transfers to the ICU

• Learning Objective 2: Distinguish between real-time automated EMR-based prediction models and rapid response team (RRT) protocols

• Learning Objective 3: Analyze process of developing, validating & implementing automated prediction models/early warning systems

• Learning Objective 4: Evaluate potential for automated prediction models to improve the early detection of at-risk hospital patients
Background
Cardiopulmonary Arrests

Annually ~209,000
In-Hospital CPA’s with high mortality rates
Early Detection is the Goal

National Patient Safety Goal:
“The early detection of physiologic deterioration in order to reduce in-hospital mortality and prevent unplanned transfers to the intensive care unit (ICU)”
Rapid Response Teams

“Team of providers is summoned to the bedside to immediately assess and treat the patient with the goal of preventing intensive care unit transfer, cardiac arrest, or death”
Rapid Response Team Call Criteria at Parkland Health & Hospital System (PHHS)

Table 2. Typical Rapid Response System Calling Criteria

Any staff member may call the team if one of the following criteria is met:

- Heart rate over 140/min or less than 40/min
- Respiratory rate over 28/min or less than 8/min
- Systolic blood pressure greater than 180 mmHg or less than 90 mmHg
- Oxygen saturation less than 90% despite supplementation
- Acute change in mental status
- Urine output less than 50 cc over 4 hours
- Staff member has significant concern about the patient's condition

Additional criteria used at some institutions:

- Chest pain unrelated by nitroglycerin
- Threatened airway
- Seizure
- Uncontrolled pain

Mixed Evidence on RRTs

Review Article
January 11, 2010

Rapid Response Teams
A Systematic Review and Meta-analysis

Paul S. Chan, MD, MSc; Renuka Jain, MD; Brahmajeet K. Nallmothu, MD, MPH; et al.


Mahara et al. Critical Care 2015:19:254

Rapid response systems: a systematic review and meta-analysis
Ritesh Mahara1,2,*, Ivan Raffaele2 and Julia Wendon1,2
Early Warning Systems a Possible Solution?
Early Warning Systems Inadequate

- **Require monitoring & activation by overburdened staff**
- **Fail to systematically monitor all patients**
- **Demonstrate only modest accuracy identifying patients at risk for CPA or death**

### Early Warning Scoring System

<table>
<thead>
<tr>
<th>MEWS (Modified Early Warning System)</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><strong>Respiratory Rate per minute</strong></td>
<td>Less than 8</td>
<td>9-14</td>
<td>15-20</td>
<td>21-29</td>
<td>More than 30</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Heart Rate per minute</strong></td>
<td>Less than 40</td>
<td>40-50</td>
<td>51-100</td>
<td>101-150</td>
<td>More than 120</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Systolic Blood Pressure</strong></td>
<td>Less than 70</td>
<td>71-80</td>
<td>81-100</td>
<td>101-150</td>
<td>More than 150</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Conscious Level (AL/PLU)</strong></td>
<td>Unresponsive</td>
<td>Responds to Pain</td>
<td>Responds to Voice</td>
<td>Alert</td>
<td>New agitation</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Temperature (°C)</strong></td>
<td>Less than 35.0</td>
<td>35.1-36</td>
<td>36.1-38</td>
<td>38.1-38.6</td>
<td>More than 38.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hourly Urine</strong></td>
<td>Less than 10mls/hr</td>
<td>Less than 30mls/hr</td>
<td>Less than 45mls/hr</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

*If the MEWS score is deteriorating: the ward Nurse or Duty Doctor must attend.*

*If the score for your patient 4 or more? Perform observations at least 2 hourly. Ensure medical advice is sought and contact Outreach Team (see below).*
What else can be done to proactively identify patients at risk for clinical deterioration?
Complexity of the Issue

Predicting Out-of-ICU adverse events through predictive modeling is incredibly complex

Predicting out of intensive care unit cardiopulmonary arrest or death using electronic medical record data

Carlos A Alvarez, Christopher A Clark, Song Zhang, Ethan A Halm, John J Shannon, Carlos E Giroud, Lauren Cooper and Ruben Amarasingham

Early Automated Model vs MEWS

Observed rates of out-of-ICU resuscitation and death events stratified by quintiles of risk in the automated model.

Clinical Deep Learning

Raw Lab and Vital Sign Values with time stamps

- Low Alb
- High TBii
- High INR
- Rising BUN
- Rising Creat
- High or Rising Lact.
- Low or High WBC
- Incr. Temp
- Rapid Pulse
- Low or Falling BP

Various Trending and Thresholded Primitives

- Liver Failure
- Kidney Failure
- Infection
- SIRS

Septic Shock
Automated Early Warning Systems Workflow

1. **Predictive model generates a risk score**

2. **Alert fired on “high risk” patients**

3. **RAT Nurse Assesses Patient**

4. **Monitor with no action taken**

5. **Takes Action**
Early Model: Automated EWS 1.0

- The program began at PHHS in August 2014 with version 1.0 of the Automated EWS software.

- Over this time period 338 alerts generated to RAT.

- Paused program in August 2016 to allow development of version 2.0.
Definitions

• **EWS first** = Automated EWS alert was first trigger and there were no prior RAT visits in last 24 hours

• **A Medicine service patient** is defined as having spent time on the medicine service, medicine subspecialty, PM&R, family medicine anytime during admission.
EWS First Alert with Corresponding Actions

**Auto-EWS 1.0 live mode** identified approximately 1 critically deteriorating patient on the medical service every 2 weeks that was not otherwise identified by staff.

57 cases first identified by Auto-EWS alert
Preliminary analysis shows we will need an additional 22 months of follow-up to have power to detect a 25% reduction in the hospital-wide out-of-ICU CPA rate from 3.03 to 2.27.
EWS 2.0: Feature Development and Testing
Auto-EWS 2.0 – New Features

- Auto-EWS 2.0 was prospectively tested in silent mode for 1-year prior to live mode deployment in July 2017

- Critical areas of improvement:
  1. Improve alert sensitivity and specificity
  2. Deliver the contextual reasons for the alert
  3. Method to snooze alerts that don’t warrant immediate actions
  4. Further refined filter criteria
**Improved sensitivity to detect adverse events in next 72-hours (Silent Mode Analysis*)**

<table>
<thead>
<tr>
<th>Event Type</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>179 Deaths</td>
<td>22% 28% 35% 15%</td>
</tr>
<tr>
<td>96 CPA/ARC/Codes</td>
<td>46% 9% 18% 27%</td>
</tr>
<tr>
<td>573 Unplanned ICU Transfers</td>
<td>35% 12% 13% 40%</td>
</tr>
</tbody>
</table>

**Auto-EWS has ability to provide early warning* for:**
- 63% of deaths
- 27% of code events
- 25% of unplanned ICU transfers

*Based on review of 337,833 6-hr at-risk periods from 20,813 inpatient encounters over a 1 year period of concurrent 1.0 (live) and 2.0 (silent mode) scoring
Clinical Contextual Reasons

Provide the top 1-2 laboratory, vital sign, or organ system dysfunction drivers responsible for crossing fire/alert threshold

Clinical contextual reasons are grouped into categories:

- **ABG** (related to PCO2, PO2, pH)
- **Lung** (related to Resp rate or SpO2)
- **BP** (Blood pressure related)
- **Pulse** (Pulse related)
- **Trop** (Troponin related)
- **Infection** (related to Lactate, Platelets, WBC, Temperature)
- **LOC** (related to LOC = level of consciousness)
- **Blood** (related to Hemoglobin, Hematocrit, Plats, INR)
- **Liver** (related to INR, Total bilirubin, Albumin)
- **Kidney** (related to BUN, Creat, CO2, Sodium)
Method to Snooze Alerts

RAT Nurse Assesses Patient via EHR

Alert fired on “high risk” patients

RAT in-person Assessment

Monitor with no immediate action taken

✓ Fill out QI field with reason for not seeing patient

QI field filled = Snooze for X hours
Customized filter criteria to improve operational efficiency and RAT staff time

Filter Criteria

- Exclude Certain Patients
- Exclude Certain Locations
- Last RAT Call or Pieces Alert
- PiecesQI Reason for Not Seeing Patient
- Time Since Location
- Bed & Room Assigned
- Team
- DNR & Comfort Care
- ICU, PCU, ER, Rehab, Psych, Radiology & Procedure Areas, Cath Lab, OR, L&D, Dialysis
- Hours since RAT alert. Hours since Pieces alert.
- Hours since PiecesQI Reason recorded for Not Seeing Patient
- Hours since patient has been out of ICU or procedure suite before alert.
- Patient must have a bed/room assigned
- Will only generate alerts on Medicine patients
Potential Cost Savings Opportunities
(Silent Mode Analysis*)

Over a 12-month EWS 2.0 silent mode evaluation period, there were 234 patients identified early on by Automated EWS (but not by nurse call) who subsequently had an event (emergent transfer to ICU, CPA/ARC/Code, or Death) in the next 72 hours.

* ICU costs estimated at $2,759 per day based on Becker Hospital Review (https://www.beckershospitalreview.com/finance/average-cost-per-inpatient-day-across-50-states.html)
EWS 2.0 Live Mode: Early Results
EWS Identifies Critically Ill Patients \(\text{(Auto-EWS 2.0 Live)}\)

- A subset of patients first identified by EWS later required subsequent RAT activation by nurses.
- These patients have very high subsequent ICU transfer rates and in-hospital mortality.
More Time to Intervene Before It’s Too Late
(Auto-EWS 2.0 Live Mode)

Most cases detected by Nursing Staff were followed-by immediate deterioration within 12 hours → May be too late for some

In contrast, Automated EWS more often provided advanced warning → Earlier Initiation of Interventions
More Alerts Resulting in RAT Interventions*
(Auto-EWS 2.0 vs 1.0 Live Mode)

- Nurse Calls: 69%
- Auto-EWS First Calls: 54%

* Considers both immediate and subsequent actions taken in same admission
** Includes only cases with no recent nurse call in past 24 hours
Case Studies
Case #1

“0004 - Auto EWS Activation (Triggers: BP & Infection)"

Pt noted to be hypotensive; had melena previously and received IVF bolus for hypotension; ICU consult was placed, resident was hesitant to transfer to ICU but agreed to do so after education from RRT RN.

Shortly after arriving in ICU, pt became more hypotensive, had large bloody stool and large drop in blood counts (H/H 5.9/17.7). Pt was started on massive transfusion protocol, emergently intubated and taken to IR for mesenteric angiogram.
Case #1

Lessons:

• Ability to identify patient who needed higher level of care

• Education of providers needed and RRT members are strong advocates

Photo from: http://gomerblog.com/2016/09/sicker-patients/sick-patient/
Case #2

“2354 - Auto EWS Alert (Trigger: BP)”

Patient BP had trended up to as high as 238/115. Patient was agitated and had history of dementia and aggressive behaviour.

RAT advocated on behalf of the patient, administered Haldol and Hydralazine. BP came down to 144/66.
Case #2

“...worked great for this patient! ...caught the BP and we were able to treat the pt’s BP and hopefully prevented a stroke”

- Heather Wolf, RAT Coordinator
Summary

**Background:** Challenging to predict which patients are at risk for adverse in-hospital events such as CPA’s and ICU transfers

**Value of EWS:**

- A real-time predictive model for identifying clinically deteriorating patients in the hospital and may help optimize mobilization of resources act prior to adverse events (CPA, respiratory failure, death)
- Silent mode Auto-EWS 2.0 showed significant improvement over the 1.0 version.
- Live Mode Auto-EWS 2.0 triggered RAT assessments of not otherwise detected patients which resulted in ~1 patient per week needing immediate transfers to ICU and ~1 patient every 2 days needing significant actions taken by RAT team
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Questions

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