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AI Powered Early Warning System to Improve Patient Safety

Session #231, March 8, 2018

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Parkland Center for Clinical Innovation (PCCI)

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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

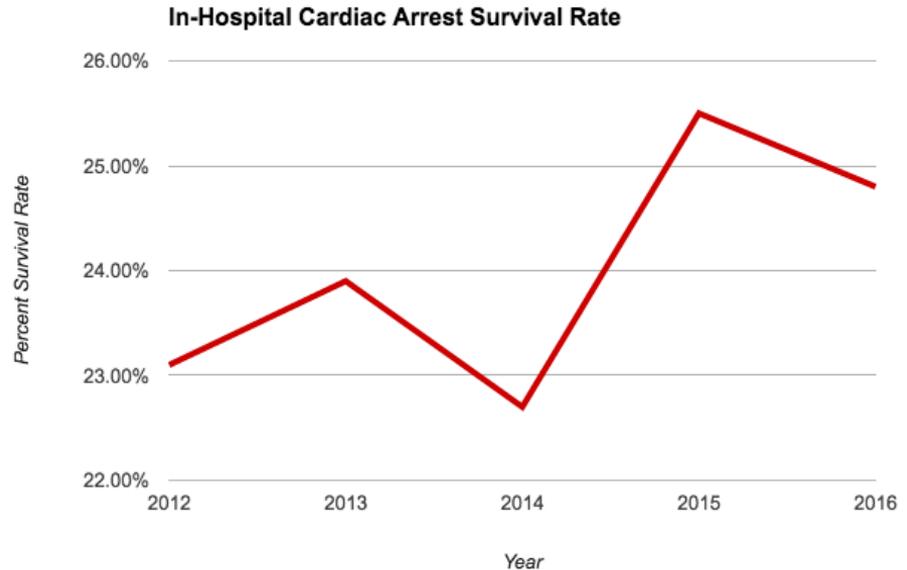
Learning Objectives

- **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 unrelieved 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; Brahmajee K. Nallmothu, MD, MPH; [et](#)

[» Author Affiliations](#) | [Article Information](#)

Arch Intern Med. 2010;170(1):18-26. doi:10.1001/archinternmed.2009.424

Maharaj *et al. Critical Care* (2015) 19:254
DOI 10.1186/s13054-015-0973-y



RESEARCH

Open Access

Rapid response systems: a systematic review and meta-analysis



Ritesh Maharaj^{1,2,3*}, Ivan Raffaele² and Julia Wendon^{1,2}

Early Warning Systems a Possible Solution?



Early Warning Systems Inadequate

MEWS (Modified Early Warning System)

	3	2	1	0	1	2	3
Respiratory Rate per minute		Less than 8		9-14	15-20	21-29	More than 30
Heart Rate per minute		Less than 40	40-50	51-100	101-110	111-129	More than 129
Systolic Blood Pressure	Less than 70	71-80	81-100	101-199		More than 200	
Conscious level (AVPU)	U nresponsive	Responds to P ain	Responds to V oice	A lert	New agitation Confusion		
Temperature (°c)		Less than 35.0	35.1-36	36.1-38	38.1-38.5	More than 38.6	
Hourly Urine For 2 hours	Less than 10mls / hr	Less than 30mls / hr	Less than 45mls / hr				

EARLY WARNING SCORING SYSTEM FOR DETECTING ADULT PATIENTS WHO HAVE OR ARE DEVELOPING CRITICAL ILLNESS
 IS THE SCORE FOR YOUR PATIENT 1-2? PERFORM 2 HOURLY OBSERVATIONS AND INFORM NURSE IN CHARGE
 IS THE SCORE FOR YOUR PATIENT 3? PERFORM 1-2 HOURLY OBSERVATIONS AND INFORM NURSE IN CHARGE
 "IF THE MEWS SCORE IS DETERIORATING : THE WARD S.H.O. OR DUTY DOCTOR **MUST ATTEND**"
 IS THE SCORE FOR YOUR PATIENT 4 OR MORE? PERFORM OBSERVATIONS AT LEAST 1/2 HOURLY. ENSURE MEDICAL
 ADVICE IS SOUGHT AND CONTACT OUTREACH TEAM (see below)



Require monitoring & activation by overburdened staff



Fail to systematically monitor all patients



Demonstrate only modest accuracy identifying patients at risk for CPA or death

What else can be done to proactively identify patients at risk for clinical deterioration?

Complexity of the Issue

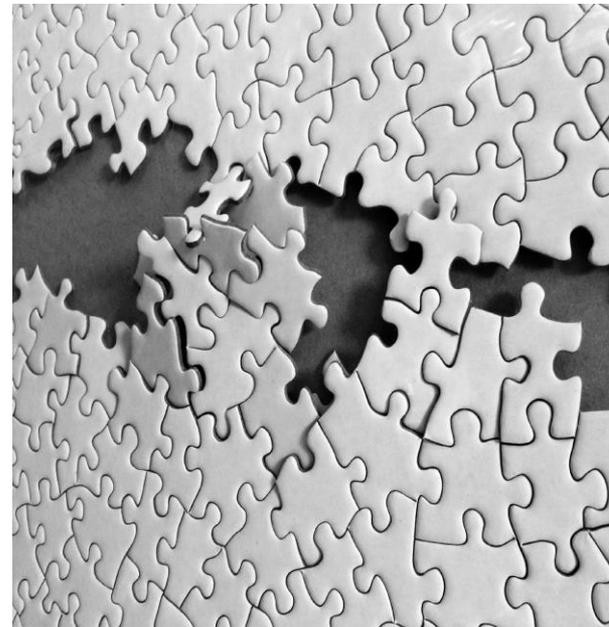
Predicting Out-of-ICU adverse events through predictive modeling is incredibly complex

RESEARCH ARTICLE

Open Access

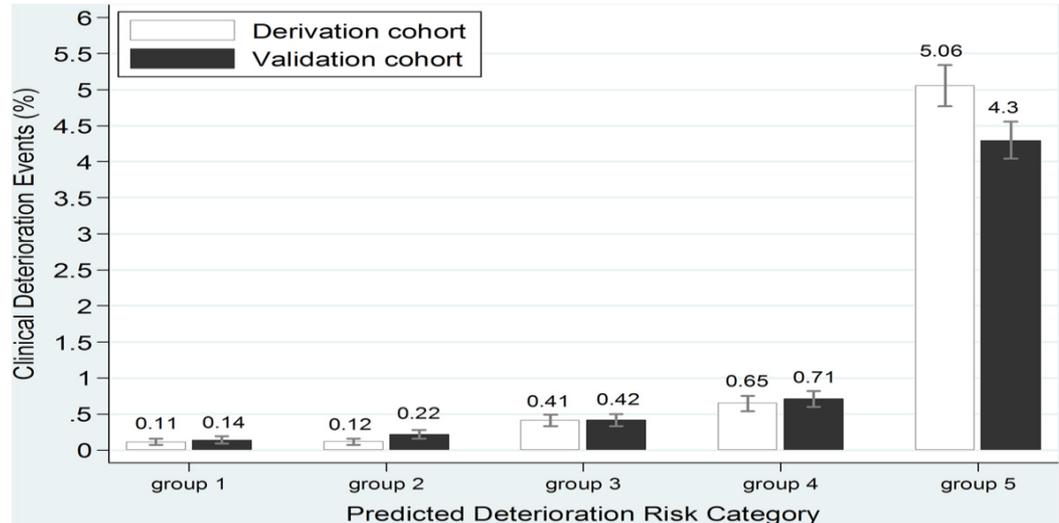
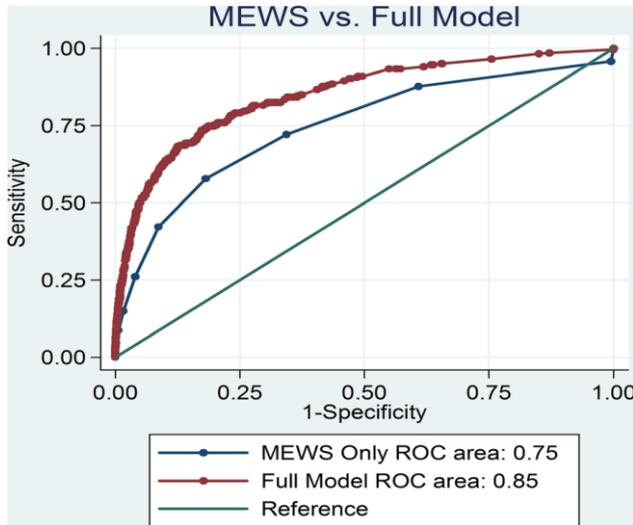
Predicting out of intensive care unit cardiopulmonary arrest or death using electronic medical record data

Carlos A Alvarez^{1,2}, Christopher A Clark², Song Zhang³, Ethan A Halm⁴, John J Shannon⁵, Carlos E Girod⁶, Lauren Cooper⁶ and Ruben Amarasingham^{2,4*}

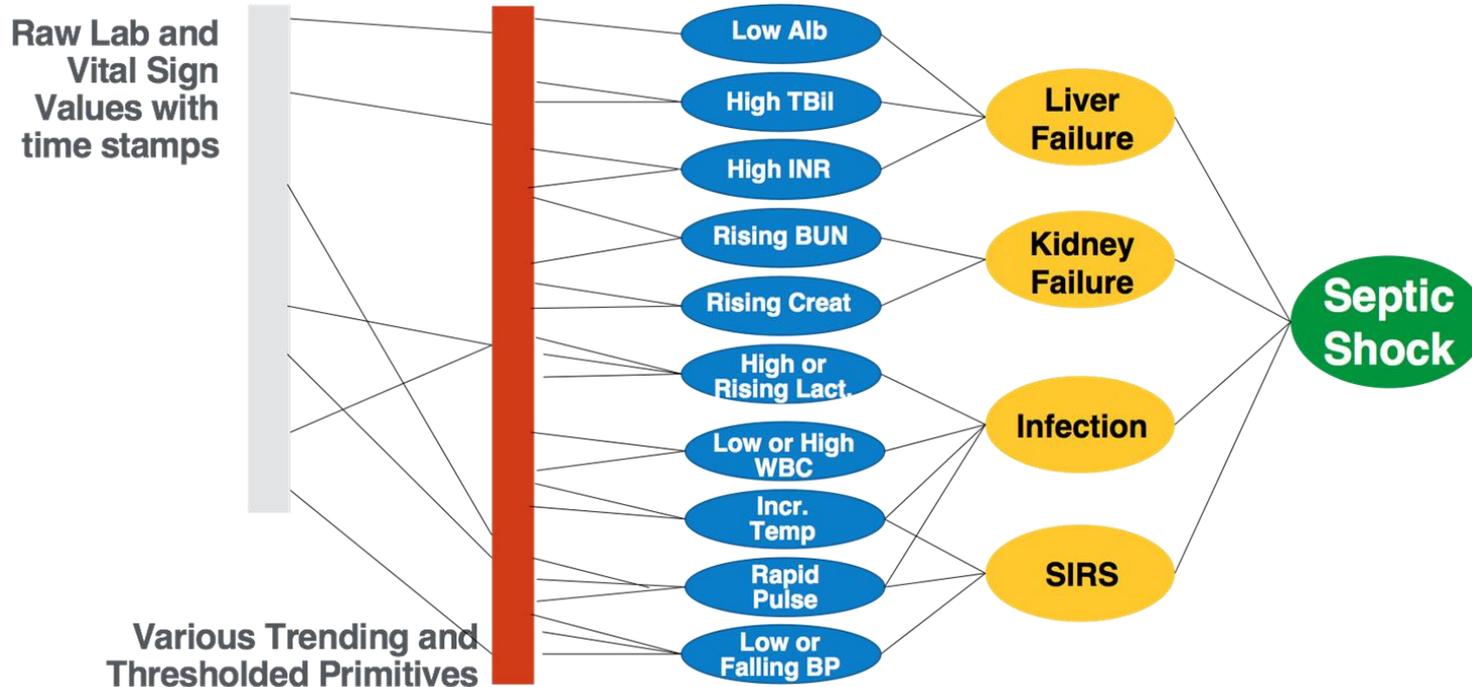


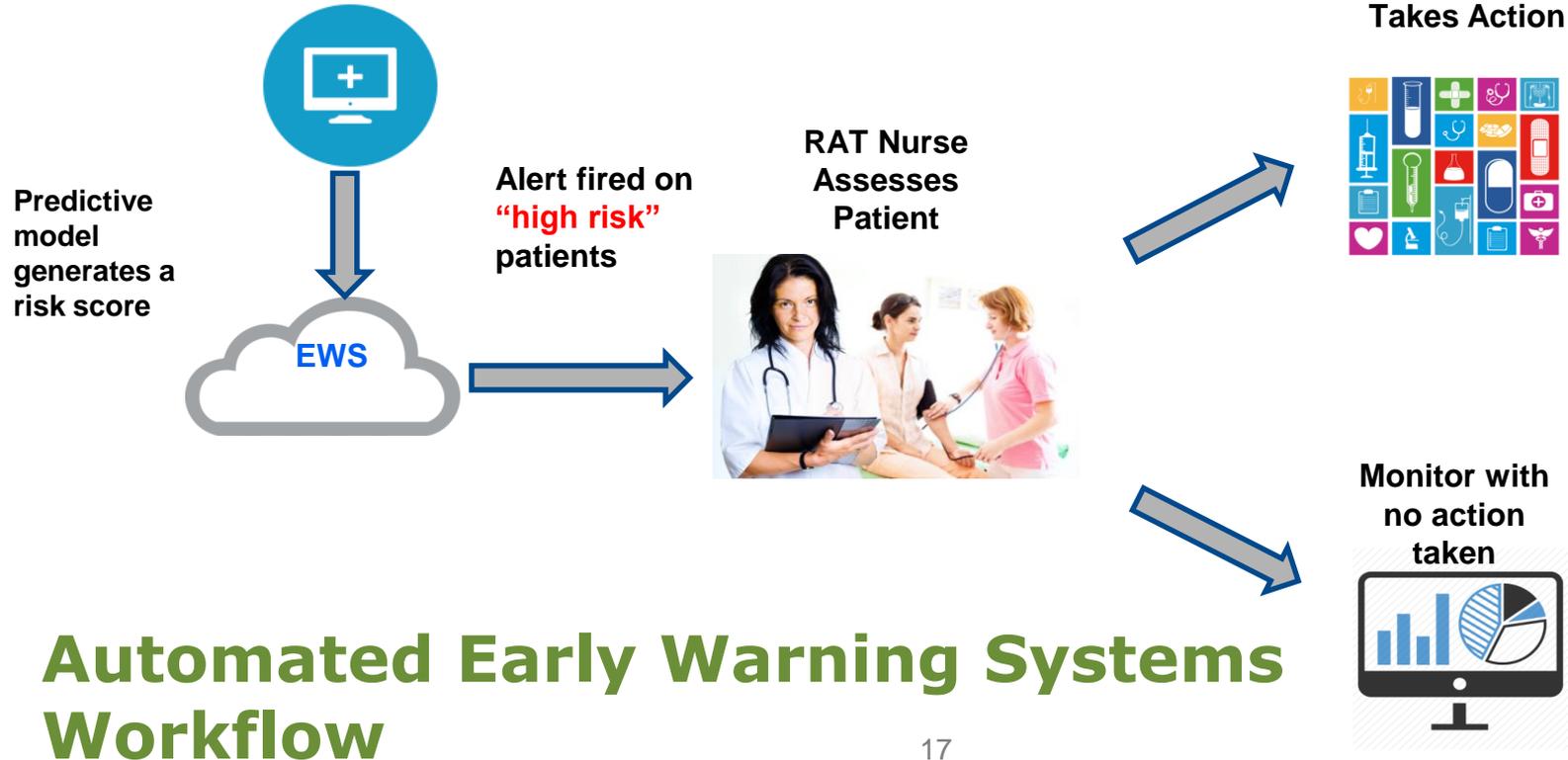
Early Automated Model vs MEWS

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



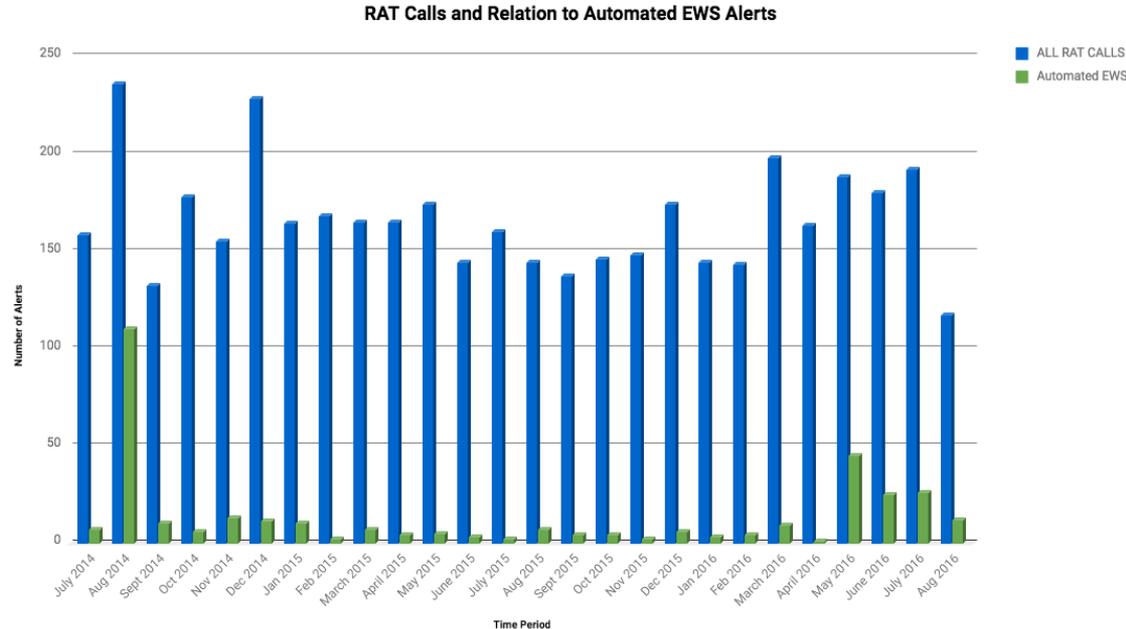
Clinical Deep Learning





Early Model: Automated EWS 1.0

- The program began at PHS 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



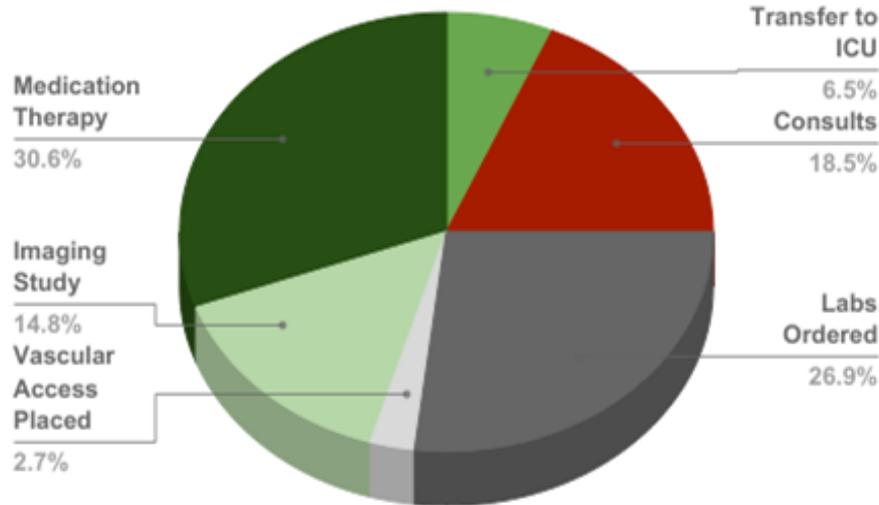
Definitions

- **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

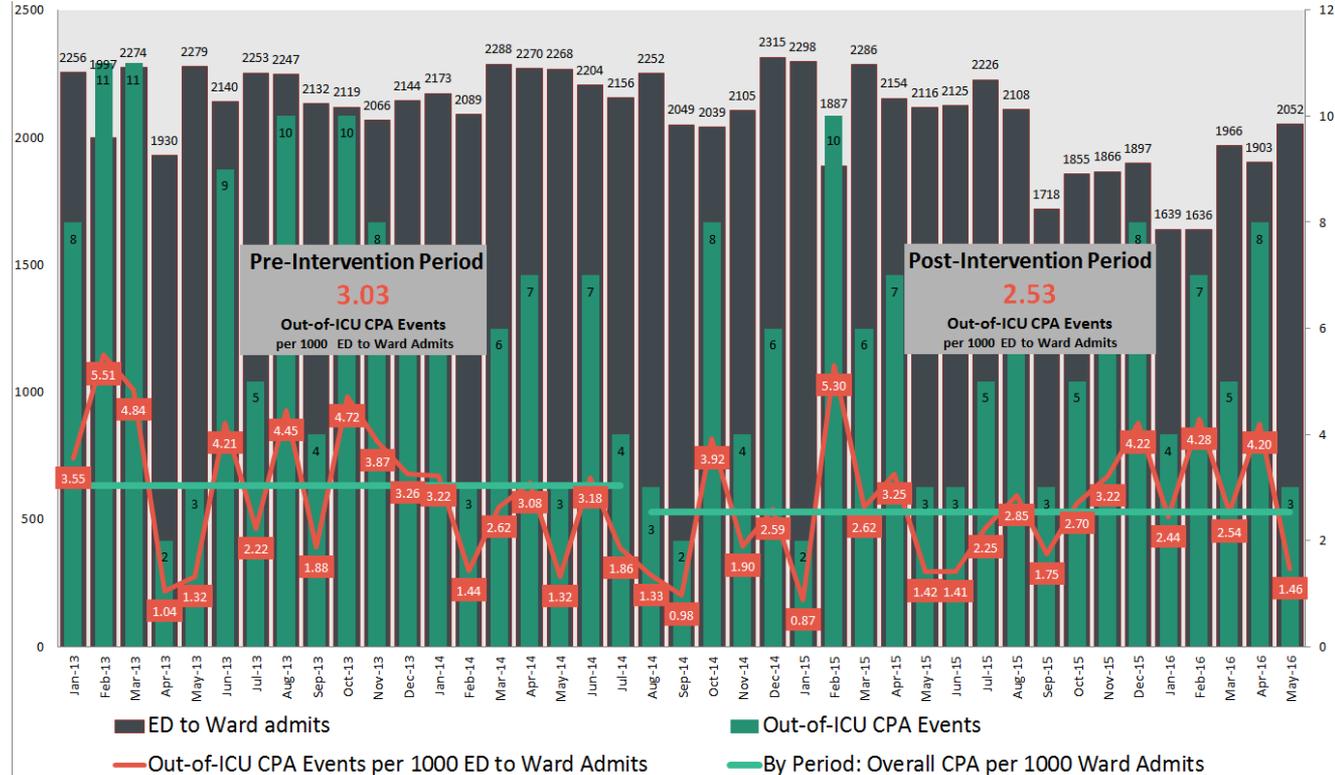
Auto-EWS 1.0 live mode identified approximately 1 critically deteriorating patient on the medical service every 2 weeks that was not otherwise identified by staff.

**57 cases
first identified
by Auto-EWS
alert**



Out-of-ICU CPA (Auto-EWS 1.0 Live Mode)

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.

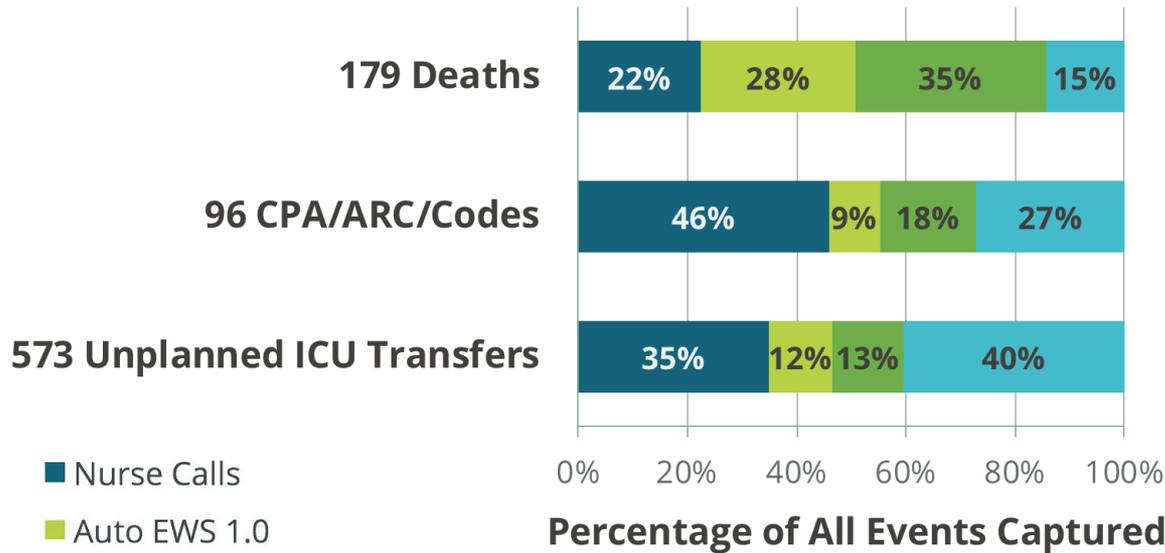


EWS 2.0: Feature Development and Testing

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*)



Auto-EWS has ability to provide early warning* for:

- 63% of deaths
- 27% of code events
- 25% of unplanned ICU transfers

- Nurse Calls
- Auto EWS 1.0
- Auto EWS 2.0
- Misses

*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



RAT in-person
Assessment

Alert fired on
“high risk”
patients



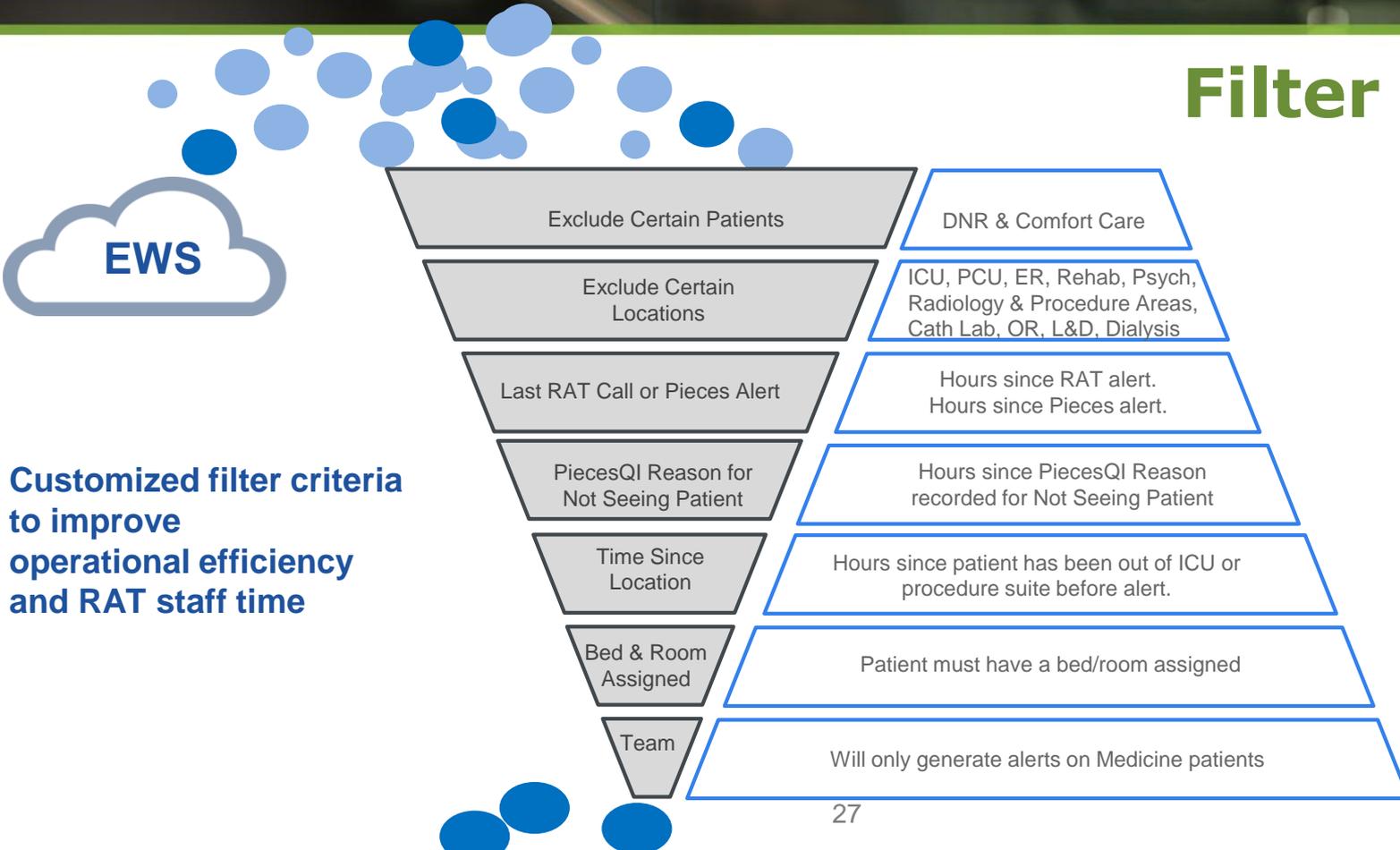
Monitor with no
immediate
action taken

✓ **Fill out QI field with
reason for not seeing patient**

CPA Reason	Blood Gas, Lung
Pieces QI	No change in clinical present... Primary nurse states patient is stable with Recent RAT call or ICU discharge follow u No change in clinical presentation from ad Erroneous entry of vital signs (or none ent Patient in procedural area/recovery - conti Other (see comments)

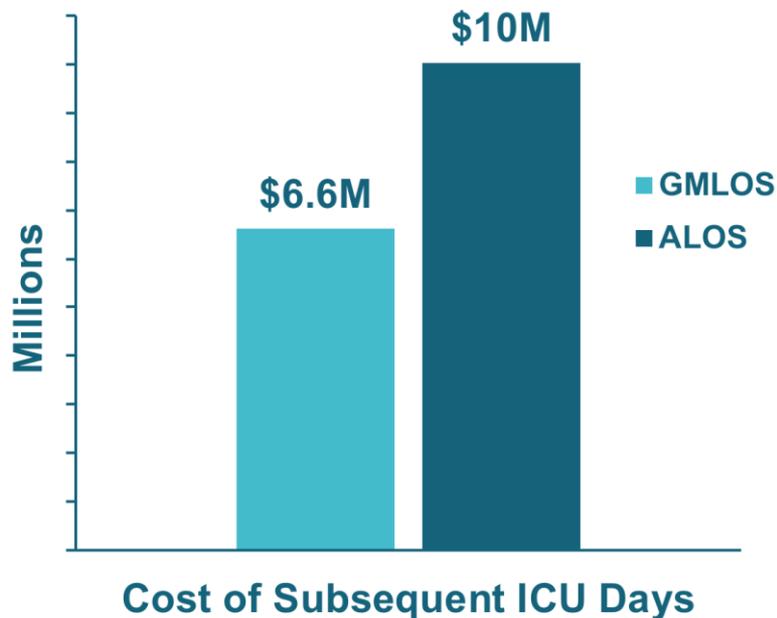
QI field filled = Snooze for X hours

Filter Criteria



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.

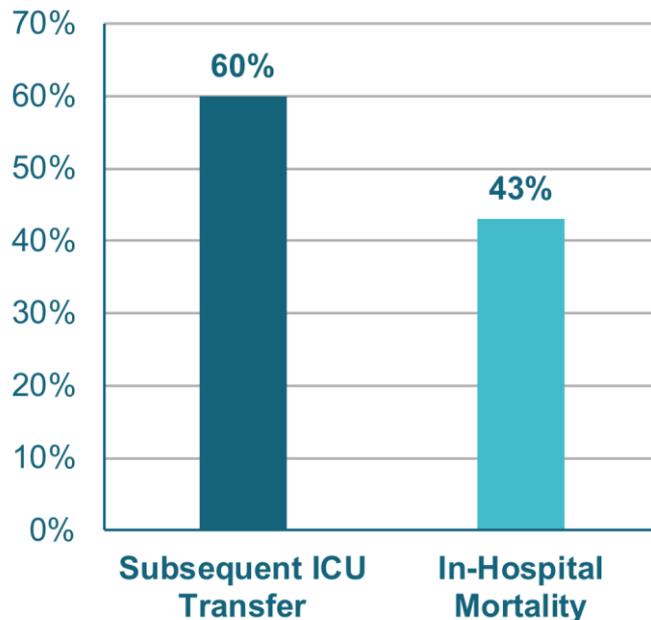


* ICU costs estimated at \$2,759 per day based on Becker Hospital Review (<https://www.beckershospitalreview.com/finance/average-cost-per-inpatient-day-across-50-states.html>)

EWS 2.0 Live Mode: Early Results

EWS Identifies Critically Ill Patients (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)

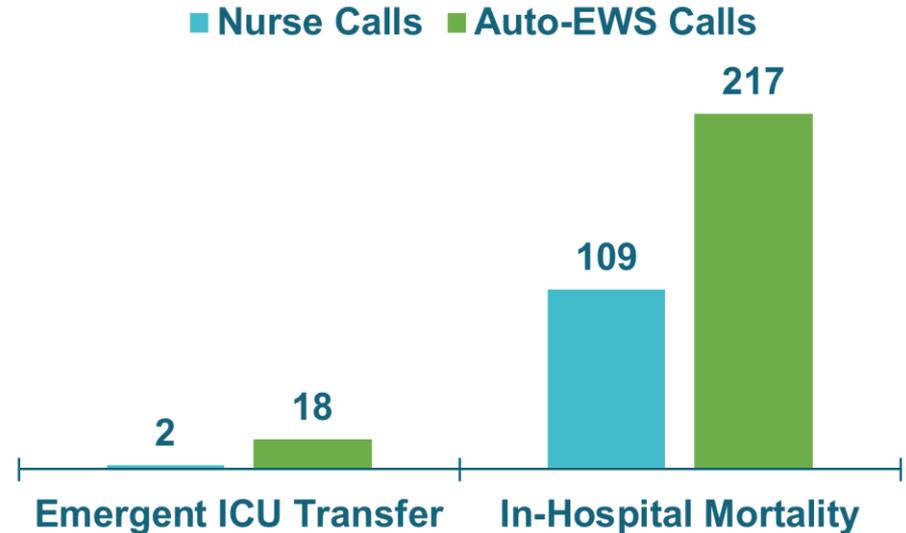
Most cases detected by **Nursing Staff** were followed-by immediate deterioration within 12 hours

→ May be too late for some

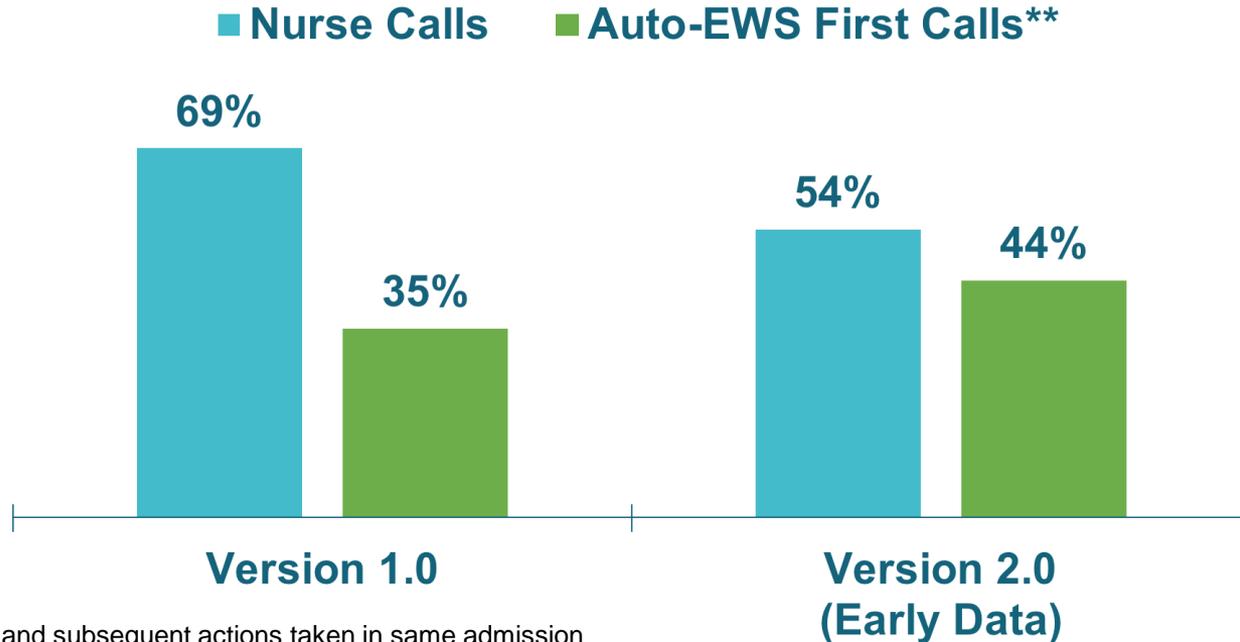
In contrast, **Automated EWS** more often provided advanced warning

→ Earlier Initiation of Interventions

Median Lead-Time (Hours)



More Alerts Resulting in RAT Interventions* (Auto-EWS 2.0 vs 1.0 Live Mode)



* 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

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

Acknowledgements

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Questions

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