Acute Care Analytics with Real World Impact for Patients and Providers

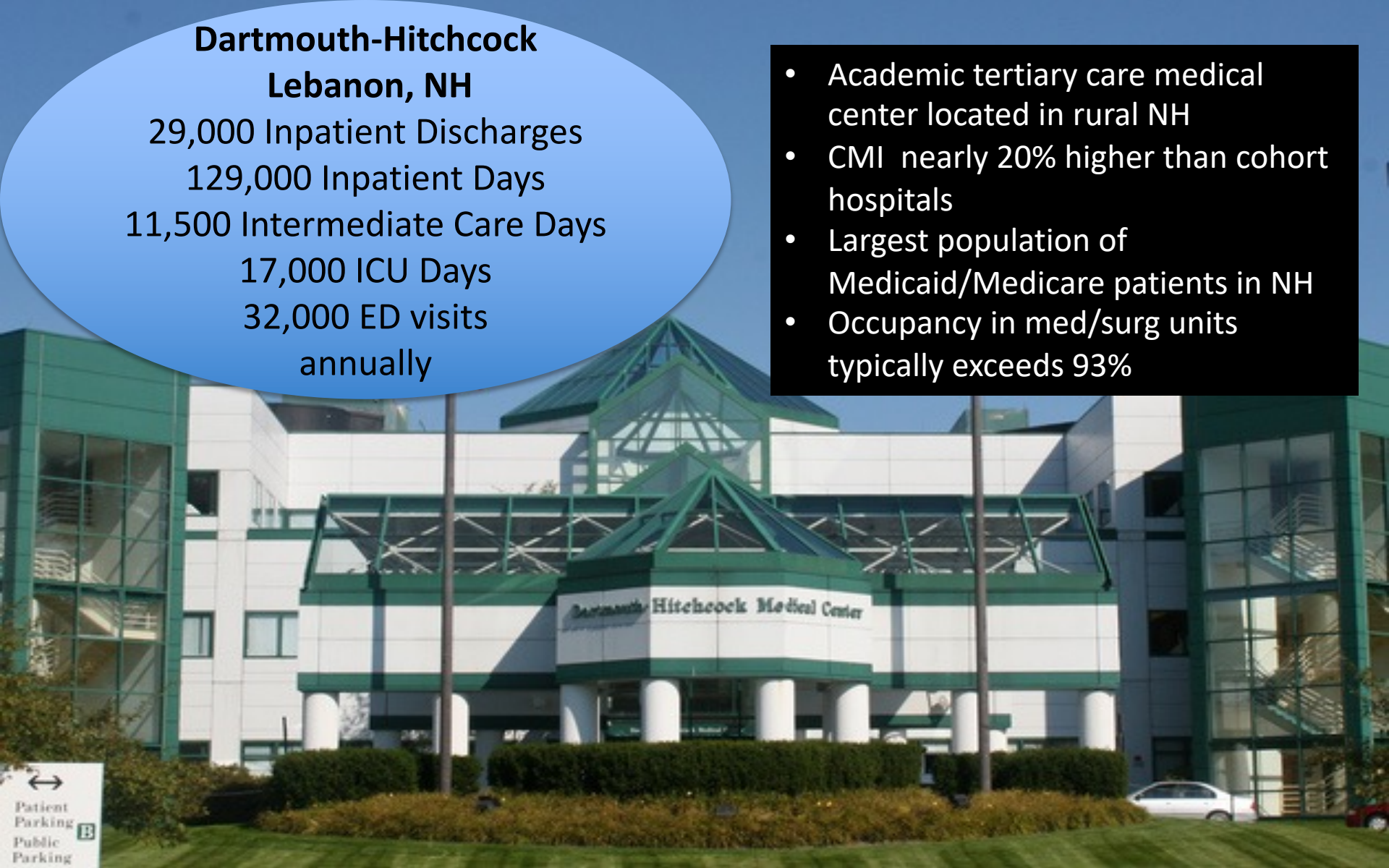
Sue McGrath, Ph.D.
susan.p.mcgrath@hitchcock.org
Associate Professor of Anesthesiology
Director, Surveillance Analytics Core
Dartmouth-Hitchcock Medical Center

D-H Surveillance Analytics Team

The work described herein is the product of multidisciplinary team effort spanning nearly 25 years. Contributors include: George Blike, MD; Irina Perreard, PhD; Krystal McGovern, RN, MSN, MBA; Todd MacKenzie, PhD; Matt Stone; Josh Ramos, MD; Josh Pyke, PhD; Andreas Taenzer, MD; Melissa Garland, RN; Kelly Converse, RN; Colin Skinner, MBA; Nancy Karon, RN; Klaus Christoffersen, PhD

Disclosure

Susan McGrath, Ph.D. declares a consulting relationship with Masimo, Inc. related to surveillance monitoring education. Masimo did not review or influence the content of this presentation.



Dartmouth-Hitchcock
Lebanon, NH
29,000 Inpatient Discharges
129,000 Inpatient Days
11,500 Intermediate Care Days
17,000 ICU Days
32,000 ED visits annually

- Academic tertiary care medical center located in rural NH
- CMI nearly 20% higher than cohort hospitals
- Largest population of Medicaid/Medicare patients in NH
- Occupancy in med/surg units typically exceeds 93%

Motivation

- Patient in 30s, admitted to general care unit after minor surgery
- History of anxiety and pre-existing conditions, assessed & determined to represent little perioperative risk
- Medication given for anxiety and opioids for pain
- Initial post-op assessments normal
- Patient found dead by a nurse upon entering room for vital signs assessment

GCU Surveillance Monitoring Approach

Patient Room

Patient-worn pulse oximetry sensor

Bedside patient monitors with visual and audible alarms

Outside the Patient Room

Unit-level data viewing station

Devices for directed alarm notification

- Continuous monitoring with pulse oximetry
- Entire stay for all patients in the general care setting
- Attention redirection with directed notification,

surveillance configuration for alarm management

Patient Safety Systems Roadmap

General Care Continuous Monitoring System

Establish continuous monitoring, trend analysis, deterioration pattern recognition tactics at the bedside to support deterioration detection

Integrated Inpatient Surveillance System

Integrate surveillance concepts with telemedicine architecture and workflows across all inpatient care settings to provide support for:

- Patient placement
- Resource allocation
- Rescue activation

Multi-site Inpatient Surveillance System

Expand surveillance system to affiliates to optimize support

Outpatient Surveillance System

Extend surveillance system to outpatient care for support of chronic condition monitoring and acute care consultation

Comprehensive Curated Data

Continuous monitoring data

- Oracle dB with continuous pulse oximetry data (1 Hz) in general care since Dec 2007
- ~220 adult med/surg and pediatric beds admit to discharge
- >400,000 inpatient visits

Calculated characteristics

- Charlson, case mix indices
- State scores- NEWS, NEWS2, MEWS, qSofa

Electronic health record

- Epic EHR patient-level records
- Admit discharge transfer, diagnoses codes, procedures, medications, labs, history

Rescue and safety databases

- All rescue activities (bedside consultations, RRT, codes) with type, time, disposition
- Safety event activity, e.g., Narcan administration

Impact of Surveillance Data Analysis

Applications

- Patient safety system design and baseline performance
  Operational performance and maintenance
- Quality assurance and patient safety
- Research and innovation

Approaches

- Impact metrics such as transfers, disposition, rescues, alarms, utilization, cost (scale: thousands of patient days)
- Patterns of physiologic data (scale: trillions of SpO2, PR data points)

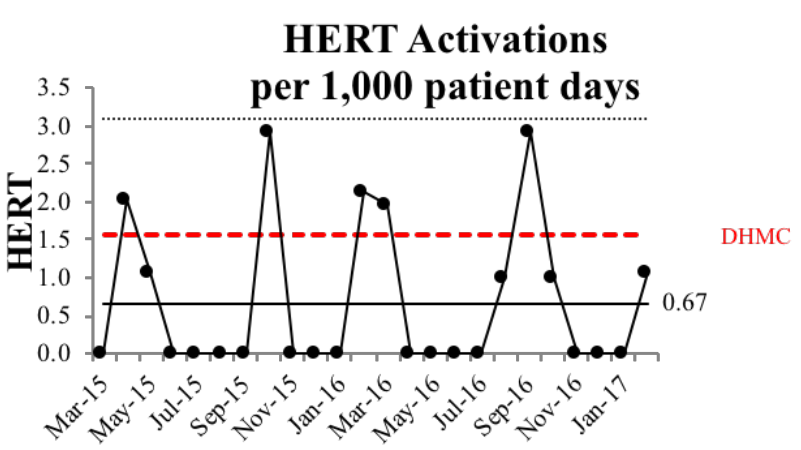
Pilot System Performance Impact

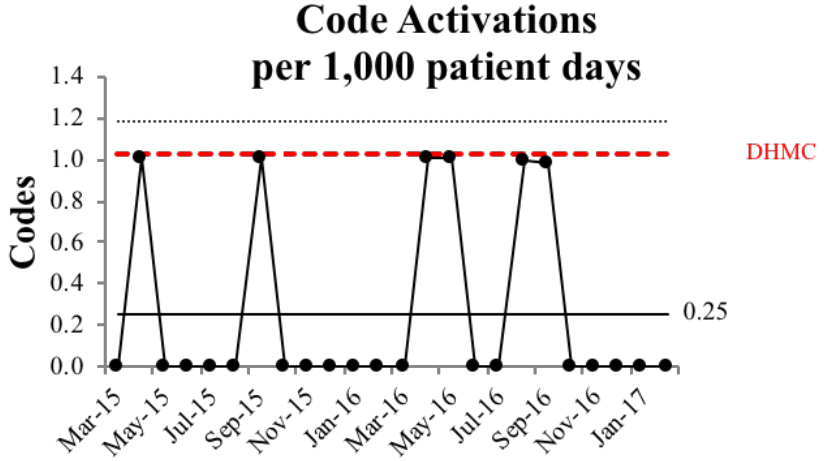
Surveillance approach implemented with continuous pulse oximetry platform to prevent unwitnessed arrests produced:

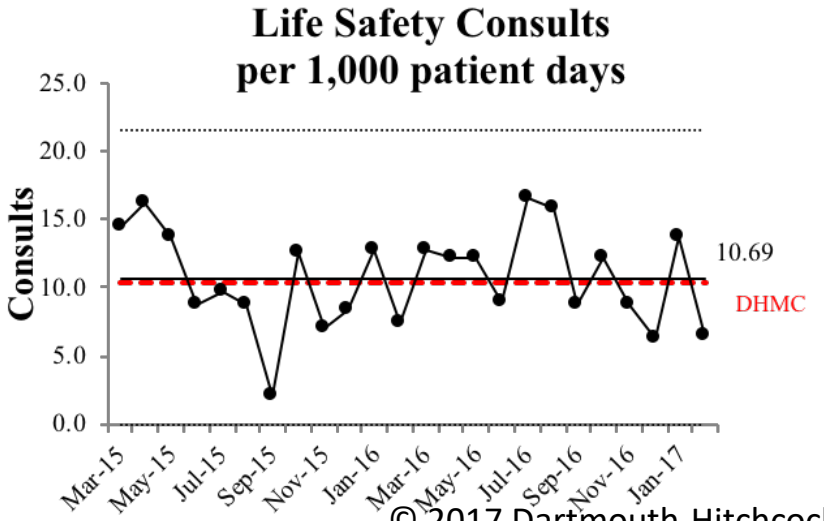
- 48% reduction in transfers to higher levels of care
- 65% reduction in rescue events
- $1.3-1.5M annual opportunity cost savings/unit
- Typical alarm rates 2-4 per patient per 12-hour shift
- ~85% of all alarm conditions are resolved within 30 seconds and > 99% before escalation is triggered

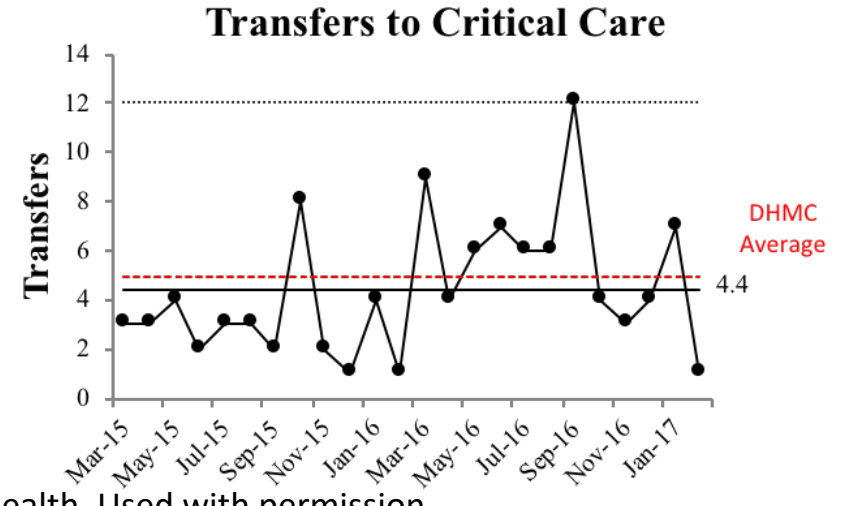
From: McGrath S, Taenzer A, Karon N, Blike G. Surveillance Monitoring Management for General Care Units: Strategy, Design and Implementation. *Jt Comm J Qual Patient Saf*. 2016 July; 42(7): 293-302 and Taenzer AH, Pyke JB, McGrath SP, Blike GT. Impact of Pulse Oximetry Surveillance on Rescue Events and Intensive Care Unit Transfers. A Before-and-After Concurrence Study. Anesthesiology 2010, 112: 282-7.

Sustained Performance - Pilot Unit 10 Years









Opioid-induced Mortality

10-year retrospective analysis of 126,697 patient discharges with review of harm/mortality related to opioid administration

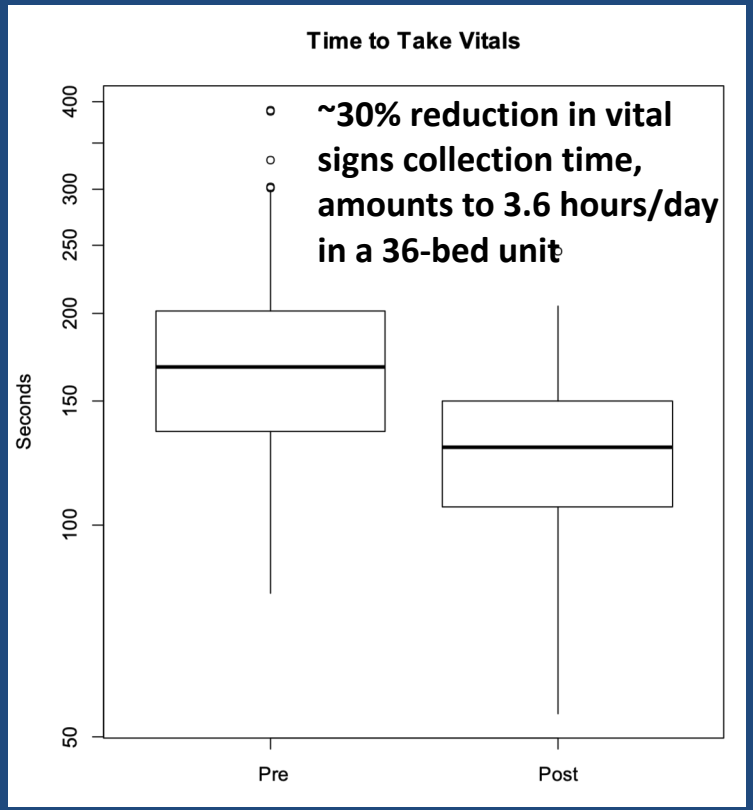
- No deaths in monitored patients
- One death where surveillance monitoring was available but not in use (0.9 deaths per 100,000 at risk patients)
- Three deaths in unmonitored units (19.73 deaths per 100,000 at risk patients)

McGrath S, McGovern K, Perreard I, Huang V, Moss L, Blike G. Inpatient Respiratory Arrest Associated with Sedative and Analgesic Medications: Impact of Continuous Monitoring on Patient Mortality and Severe Morbidity. *J Patient Saf.* 14 March 2020. DOI: 10.1097/PTS.0000000000000696.

Clinician & Patient Impact – Upgrade Pilot

- Device integration for EMR data capture
- ADT integration with barcode admit/discharge
- Integrated blood pressure and temperature sensors
- Wireless monitoring
- Bedside trends and ability to add data for EMR integration

Staff & Patient Impact - Root & Radius Pilot



- Increased patient monitoring time
- Access to patient data while ambulating
- Reduced entanglement issues
- Increased vitals accuracy
- Reduced vital signs capture and validation time
- Very high staff acceptance
- More accurate utilization info

McGrath SP, Perreard IM, Garland MD, Converse KA, Mackenzie TA. Improving Patient Safety and Clinician Workflow in the General Care Setting With Enhanced Surveillance Monitoring. IEEE Journal of Biomedical and Health Informatics. 2019 Mar;23(2):857–66.

Change Management

Describing normality and demonstrating applicability in multiple populations

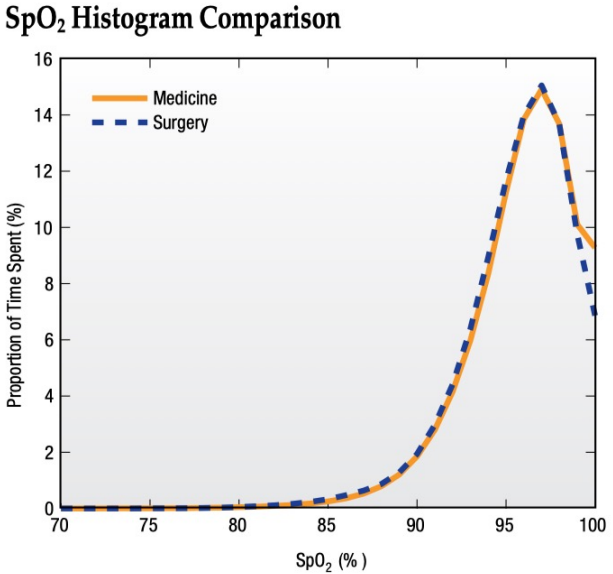


Figure 1: Distribution of oxygen saturation by pulse oximetry comparing patients on surgical and medical units.

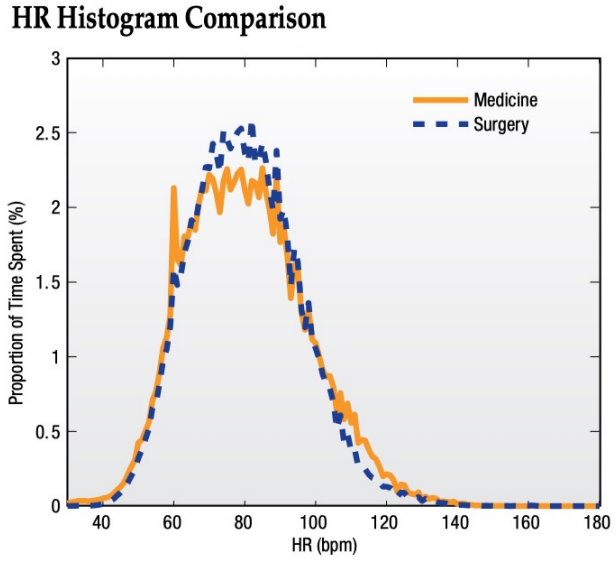
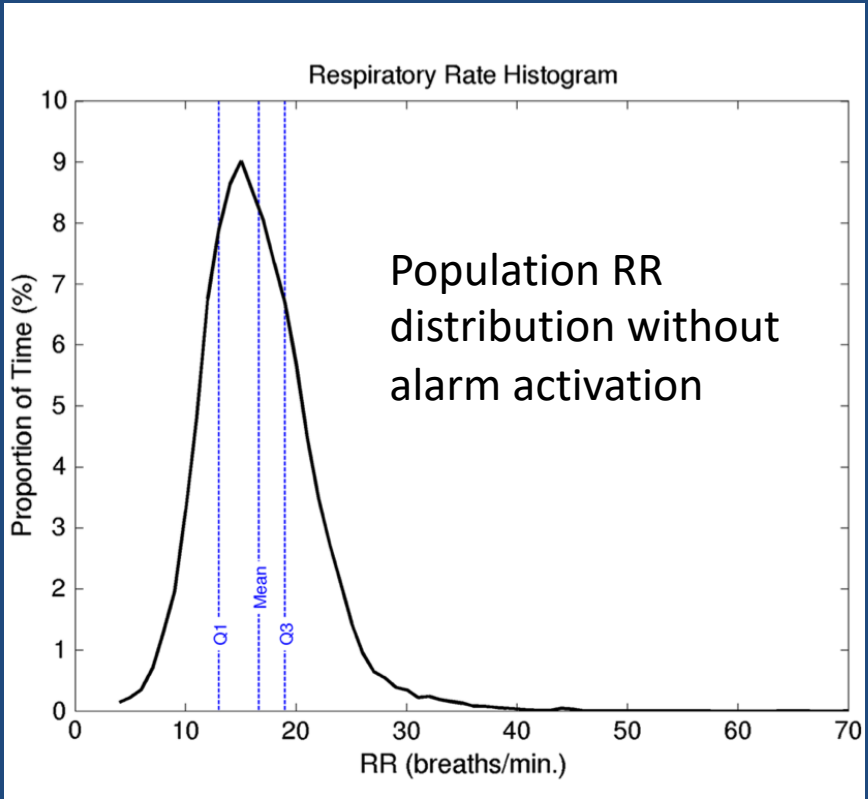


Figure 2: Time spent in heart rate states comparing patients on surgical and medical units.

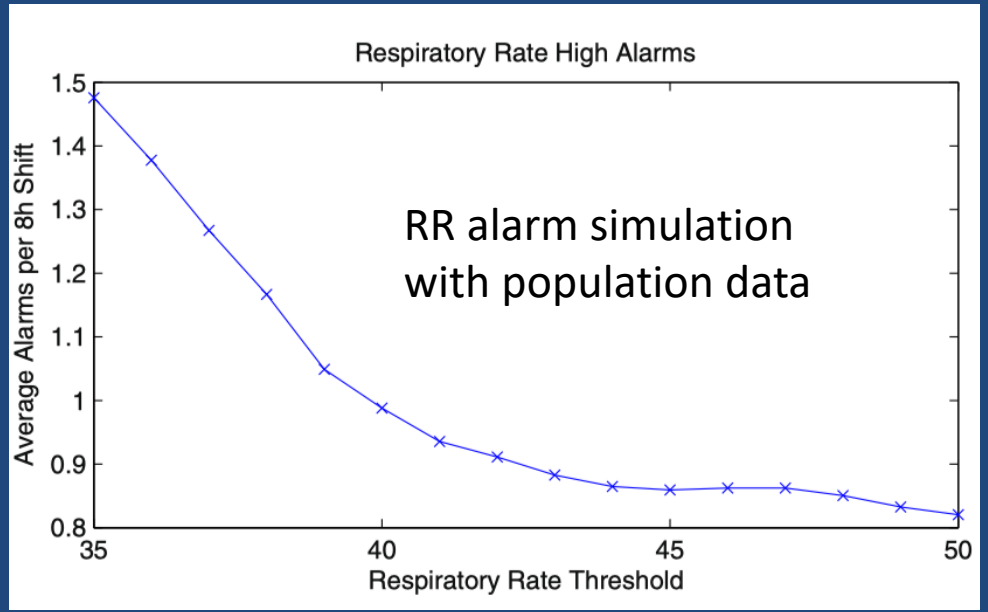
- 6800 patient days
- 500 million data points per parameter

From: Taenzer AH, Blike GT. Patient Surveillance - The Dartmouth Experience. *APSF Newsl*. 2012;Spring-Summer:1-4.

Empirical design- alarm limit selection



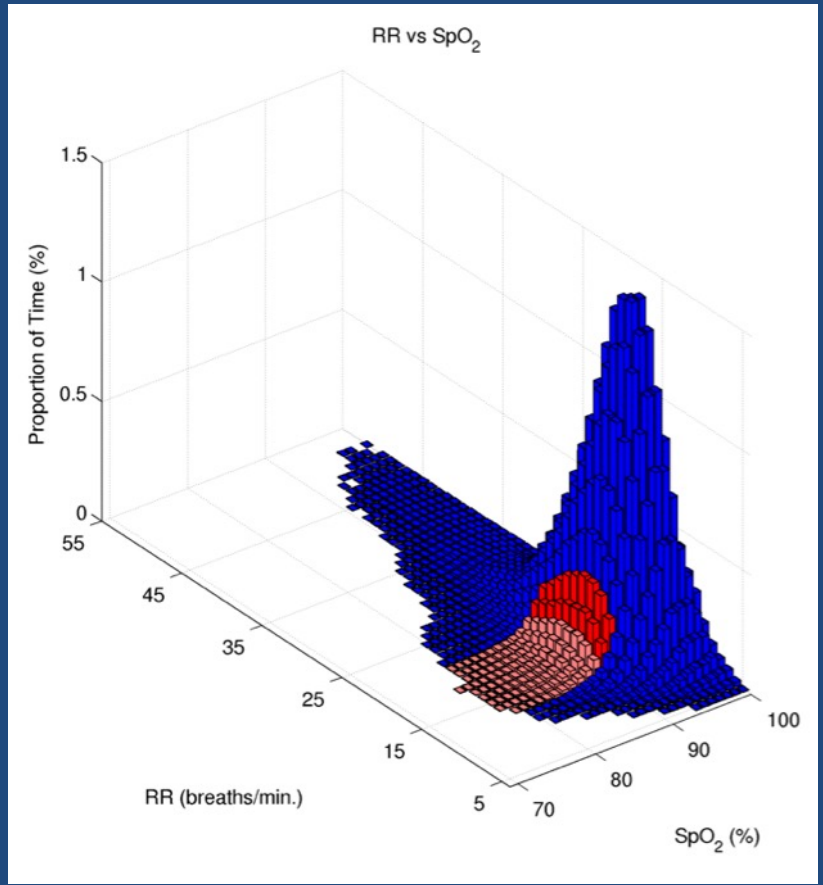
- 4324 patient days
- >374 million data points



From: McGrath S, Pyke J, Taenzer A. Assessment of continuous acoustic respiratory rate monitoring as an addition to a pulse oximetry-based patient surveillance system, *J Clin Monit Comput*, 2017 June; 31(3): 561-569.

Empirical design- directed notification signal selection

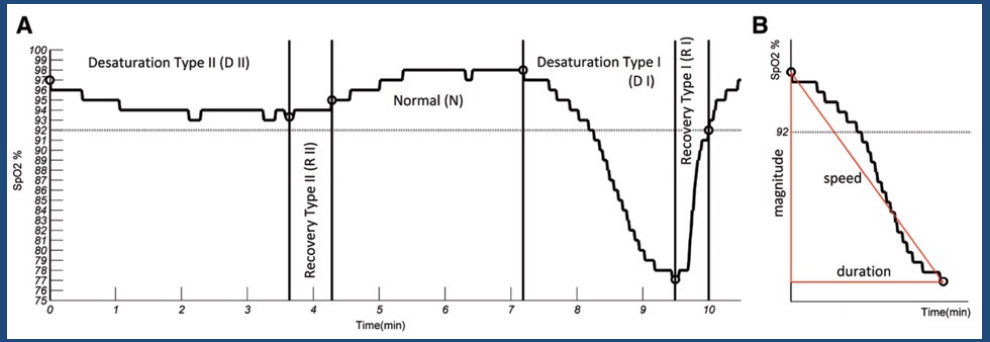
- Addition of acoustic respiratory rate monitoring to pulse ox (> 1 billion data points)
- Accurate, reliable performance
- Good patient acceptance
- During 5% of time SpO2 was less than 90%, RR values were normal 71% of the time



From: McGrath S, Pyke J, Taenzer A. Assessment of continuous acoustic respiratory rate monitoring as an addition to a pulse oximetry-based patient surveillance system, *J Clin Monit Comput*, 2017 June; 31(3): 561-569.

Population safety- supplemental O2

Can patients on supplemental O2 be safely monitored with pulse oximetry?



STATES	O2 Group % time (95% CI)	RA Group % time (95% CI)	p-value
Desaturation (all Types)	18.6 (12.0 - 25.2)	27.1 (20.9 – 33.2)	0.06
Recovery	4.00 (2.2-5.7)	8.4 (4.6 – 12.3)	0.04
Normal	77.4 (69.7 – 85.1)	64.5 (56.4 – 72.6)	0.02

Desaturations in patients breathing room air vs. those receiving supplemental O2 (~ 6 million data points). Average proportion and 95% CI of total monitored time in desaturation, recovery and normal states.

From: Taenzer AH, Perreard IM, MacKenzie T, McGrath SP. Characteristics of Desaturation and Respiratory Rate in Postoperative Patients Breathing Room Air Versus Supplemental Oxygen: Are They Different? Anesth Analg. 2018 Mar;126(3):826–32.

Population selection- supplemental O2

Comparison of desaturation duration, magnitude and slope between O2 and room air groups showed **no significant difference in desaturation characteristics**

DESATURATION Type I CHARACTERISTIC		Magnitude		Duration		Slope	
		RA	O2	RA	O2	RA	O2
N		29	21	29	21	29	21
Geometric Mean (95% CI)		7.2 (6.7 – 7.5)	7.7 (6.6 –9.0)	4.2 (2.6 – 6.7)	5.1 (2.3- 10.1)	1.7 (1.1 – 2.7)	1.5 (0.8 – 3.1)
Adjusted #	% Diff (95% CI)	16.7% (-5.3 - 43.6%)		-4.8% (-62.4 - 141.1%)		22.4% (-51.5% - 209%)	
	p-value	0.15		0.92		0.67	

Duration is in minutes, magnitude is in oxygen saturation percentage, and slope is in decrease of oxygen saturation percentage per minute.

From: Taenzer AH, Perreard IM, MacKenzie T, McGrath SP. Characteristics of Desaturation and Respiratory Rate in Postoperative Patients Breathing Room Air Versus Supplemental Oxygen: Are They Different? Anesth Analg. 2018 Mar;126(3):826–32.

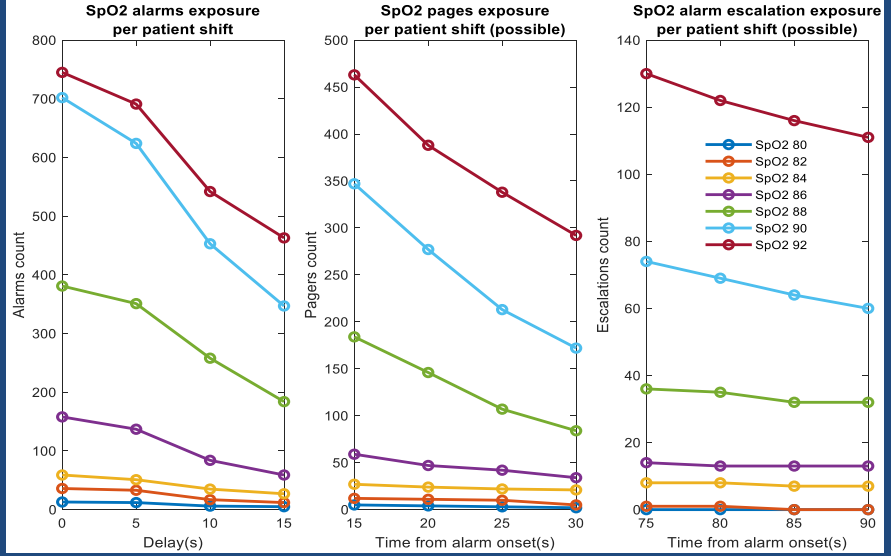
Population safety- supplemental O2

- **Preliminary** results over 5.75 years (>120K patients) looking for evidence of late recognition or harm related to supplemental O2 delivery with surveillance monitoring
- Compared to patients on room air, patients on supplemental oxygen while using surveillance monitoring **do not have**:
  - Higher rates of rescue (including nurse consultations, RRT activations) or urgent rescue (codes, stat airway)
  - More planned or unplanned* transfers to higher level of care
  - Higher rates of death after rescue

* Unplanned transfer= RRT, code or stat airway; intubation or inotropes or 3 boluses of fluid withing 1 hour of transfer

Alarm Burden Analysis

- Surveillance configuration allows unique analysis of thresholds, delays
- 8 med/surg units, 4 mos. (>19K pt days; ~2.6 B data points)
- Calculated rate, duration, nurse exposure for alarms, pages, escalations
- Key results
  - 88% alarm reduction SpO2 88 → 80 with a 0 second delay
  - 71% alarm reduction SpO2 80 with 0 second delay → SpO2 80 with 15 second delay



Surveillance
- SpO2 80%
- PR low 50 bpm
- PR high 140 bpm
- 30sec Pager Delay

Critical Care
- SpO2 88%
- PR low 50 bpm
- PR high 140 bpm
- No Delay

Condition
- SpO2 90%
- PR low 60 bpm
- PR high 120 bpm
- No Delay

Table 2

Exposure metrics for 1 nurse during a shift			Surveillance monitoring	Critical Care monitoring	Condition monitoring
Alarm Counts	Directed notification	Audible alarms	10.1	184.6	788.7
		Pages	2.0	31.3	123.1
		Escalation pages	0.4	7.2	36.2
	Broadcast notification	Audible alarms	25.2	461.4	1971.7
Alarm Duration	Directed notification	Duration	3.6 min	1.2 h	5.3 h
		Duration after page	59.5 s	18.8 min	1.6 h
		Duration after escalation	32.9 s	17.3 min	1.7
	Broadcast	Alarm duration	9.1 min	2.9 h	13.2 h

McGrath SP, Perreard IM, McGovern KM, Blike GT. Understanding the "alarm problem" associated with continuous physiologic monitoring of general care patients. Resusc Plus. 2022 Sep;11:100295. doi: 10.1016/j.resplu.2022.100295. eCollection 2022 Sep. PubMed PMID: 36042845; PubMed Central PMCID: PMC9420388.

Clinical Application of Deterioration Patterns

PEA Analysis with 80 patients; > 10 M data points

I. Baseline assessment

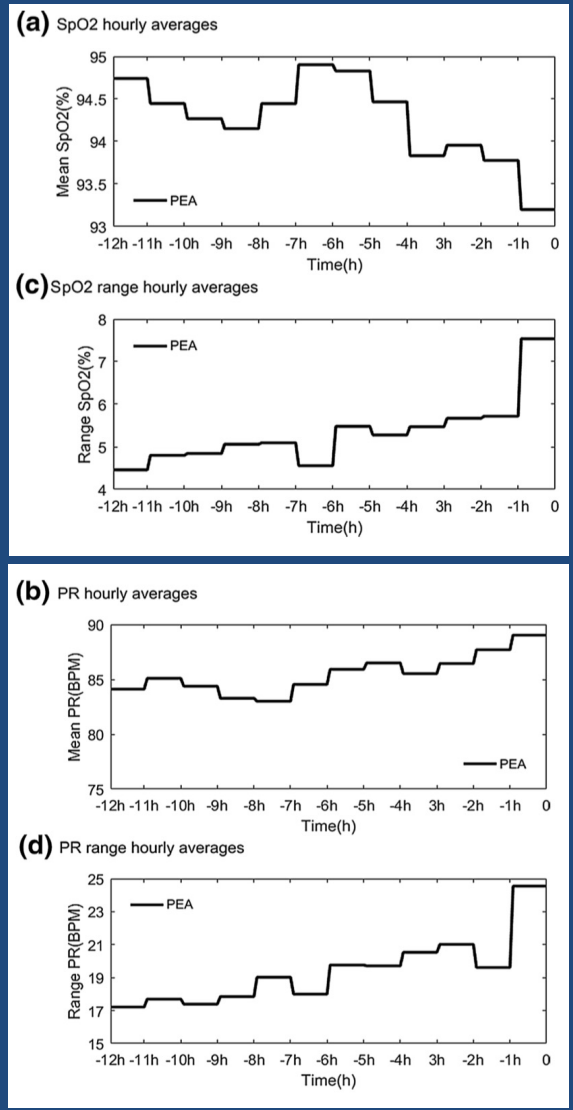
- PEA patients tend to have lower mean SpO2 and higher mean PR values than other patients
- Variability in SpO2 and PR is higher in PEA patients

II. Deterioration recognition

- Changes in variability can be seen from hour to hour starting approximately 7 h prior to PEA events

III. Rescue

- ~ 20 min before PEA events, PR mean and range are significantly different from the previous 30-min interval
- ~10 min before the PEA event, SpO2 mean and range are significantly different from the previous 30-min interval



McGrath, S, Perreard, I, MacKenzie, T, et al. Patterns in continuous pulse oximetry data prior to pulseless electrical activity arrest in the general care setting. *J Clin Monit Comput* (2020). https://doi.org/10.1007/s10877-020-00509-8.

Summary

- Large scale analysis (e.g., both “big ” and longitudinal) can significantly impact patient safety and clinical staff support in a multitude of ways
- If viewed as an integral part of healthcare delivery, this type of systems analysis provides pathways to sustained performance, improved adoption
- Problem-focused analysis (e.g., nails looking for better hammers) lead to longer term patient safety innovation and research