Monitoring in General Care Units

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Disclosure

- Boehringer Ingelheim: Speaker
- GSK: Advisory Board
- Janssen: Speaker
- Phillips: Advisory Board
- Portola: Speaker
- Sunovion: Speaker

Learning Objectives

- Upon completion of this learning activity, **participants should be able to describe the impact of respiratory deterioration in the General Care Unit**
- Upon completion of this learning activity, **participants should be able to define respiratory compromise and understand its pathophysiolo**gy
- Upon completion of this learning activity, **participants should be able to review the clinical evidence for the use of continuous oximetry and capnography in the General Care Unit**

Respiratory deterioration in GCU

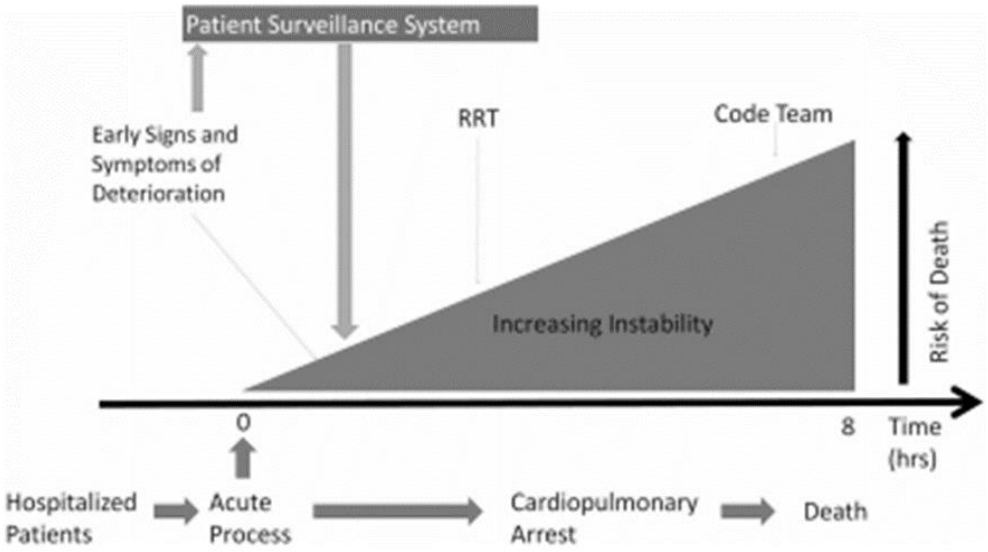
- 41% of in-hospital cardiac arrest occur in GCU [1]
- 44,000 – 64,000 annual incidence of respiratory compromise on inpatient wards with mortality of 39.4% - 49.1% [2, 3]
- Post-operative respiratory failure in non-cardiothoracic surgery: 3.8% = post-op NIV & 1.7% = reintubation & invasive ventilation [4]
- Medical inpatients: 0.91% incidence of respiratory insufficiency, arrest and failure not present on admission [5]
- Hospital-acquired respiratory failure in medical DRGs: [6]

	Hospital-acquired RF	Present on admission	P value
In-hospital mortality	32.7%	27.8%	<0.0001
30 day post-hospital mortality	15.3%	12.9%	0.0001

[1]Perman, S. *J Am Heart Assoc* 2016; 5: 1
[2]Andersen, L. *Resuscitation* 2016; 105: 123
[3]Bedoya A. *Am Thor Soc* 2019: A6478
[4]Fernandez-Bustamante A. *JAMA Surg* 2017;152:157
[5]Kelley et al. *Crit Care Med* 2012; 40: A764
[6]Lamberti J. *Am Thor Soc* 2017;195:A1893

Clinical Deterioration in GCU: Patient Surveillance System

- Patient in GCU often deteriorate (3% - 8.9% MET activation) [1]
- Adverse events often preceded by changes in vital signs (59% of in-hospital cardiac arrest preceded by abnormal intermittent VS 1-4 hr prior) [2]
- Each hour of ICU delay associated with a 3% increase risk of death [3]



from Taenzer A. *Anesthesiology* 2011; 115:421

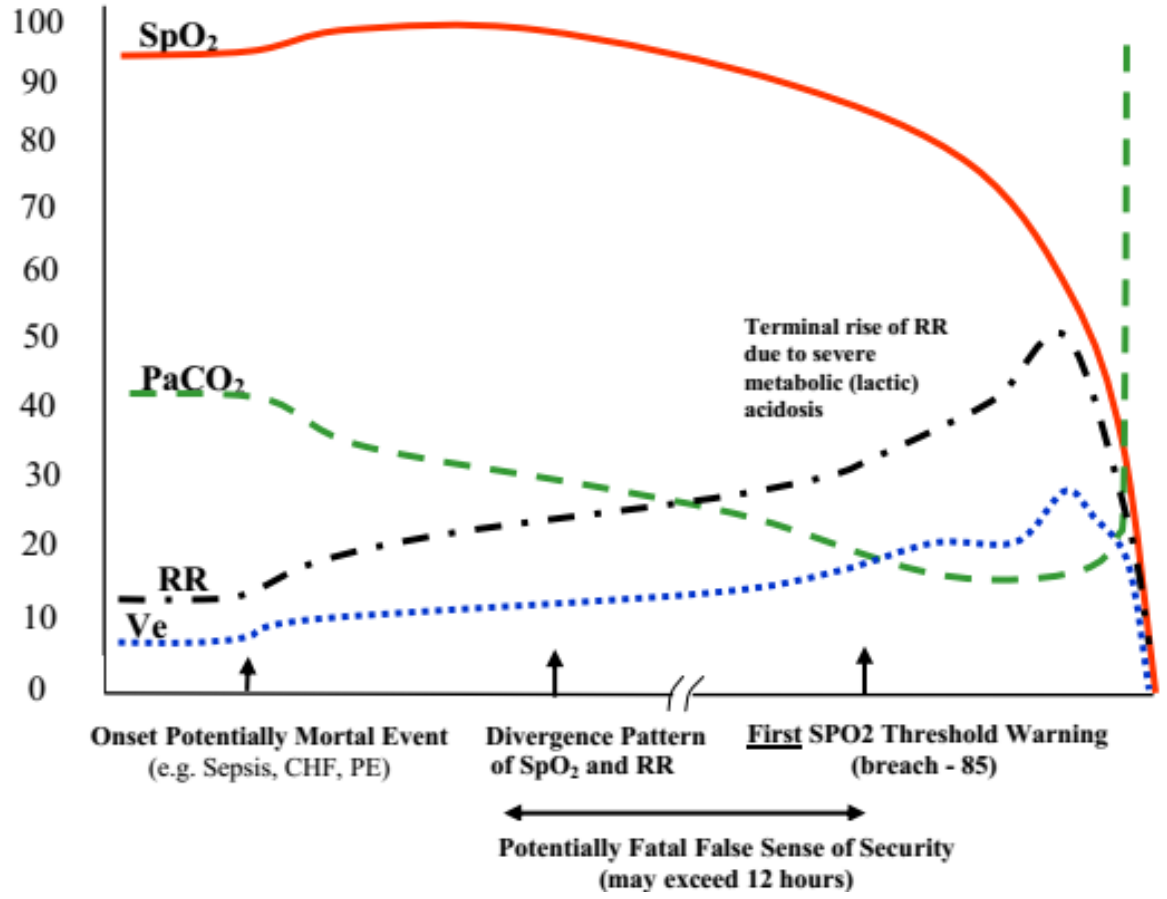
[1]Jones D. R*esuscitation* 2013, 84: 1029
[2]Andersen L. *Resuscitation* 2016; 98:112
[3]Churpek M. *J Hosp Med* 2016;11:757

Respiratory Compromise

- *"Deterioration in respiratory function in which there is a high likelihood of death but for which timely diagnosis or therapy might prevent or mitigate decompensation"*
- Pathophysiology:
  - Impaired control of breathing → e.g. opioids, procedural sedation
  - Impaired airway protection → e.g., CVA
  - Parenchymal lung disease → e.g. pneumonia, ARDS
  - Increased airway resistance → e.g. COPD exacerbation
  - Hydrostatic edema → e.g. congestive heart failure
  - RV failure → e.g. massive pulmonary embolism

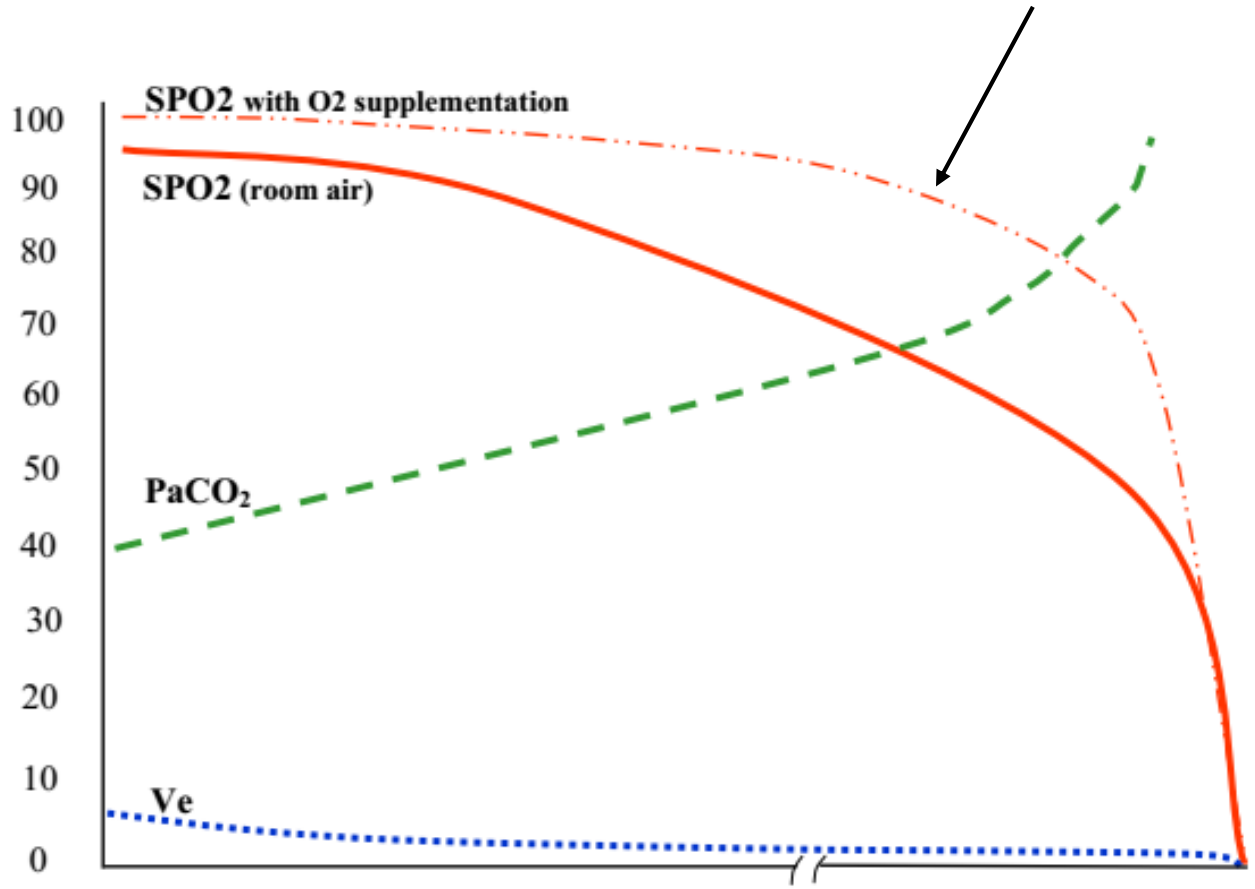
Morris T, et al. *Respir Care*. 2017; 62: 497

Patterns of Unexpected Hospital Death: Hyperventilation Compensated Respiratory Distress



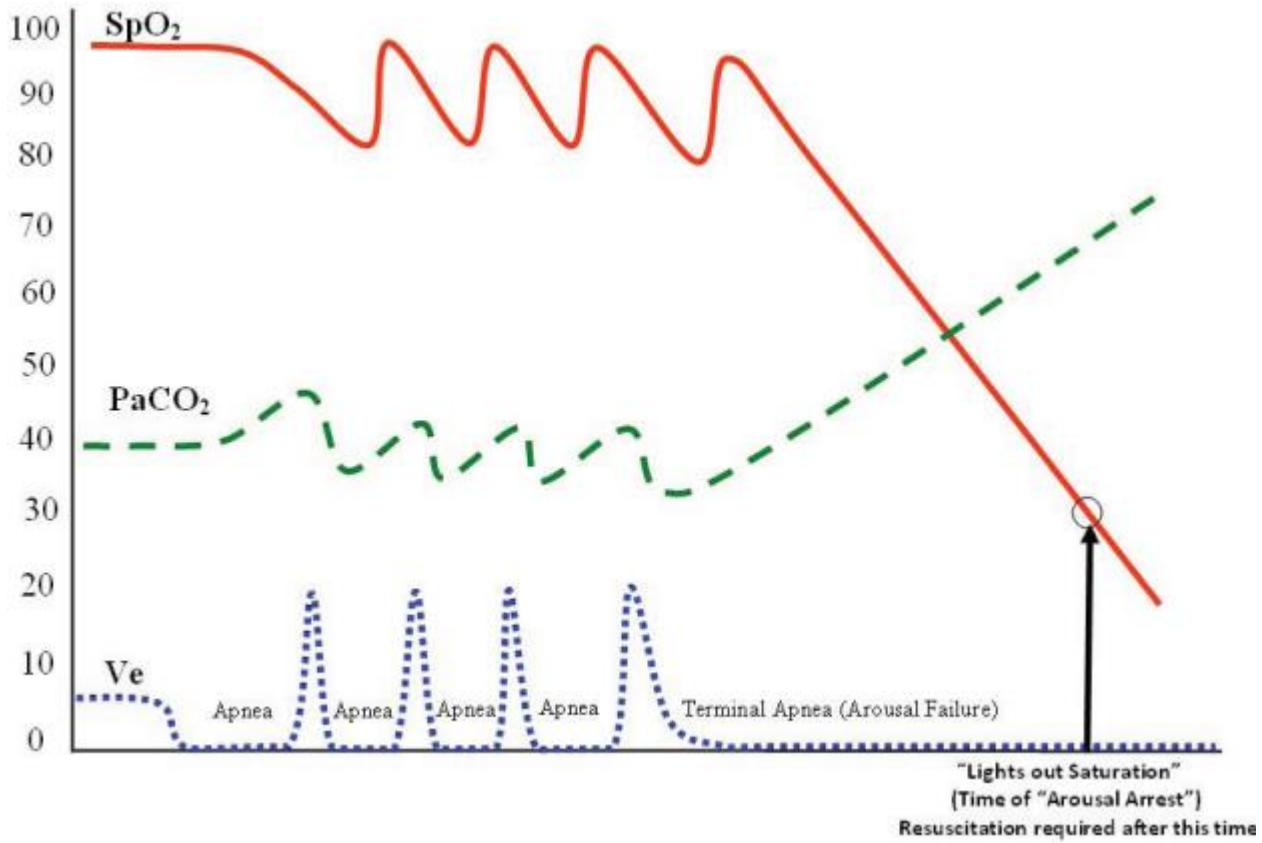
Curry P. *Patient Safety in Surgery* 2014, 8:29

Patterns of Unexpected Hospital Death: Progressive Hypoventilation



Curry P. *Patient Safety in Surgery* 2014, 8:29

Patterns of Unexpected Hospital Death: OSA with Arousal Failure



Curry P. *Patient Safety in Surgery* 2014, 8:29

Increased Risk for Respiratory Compromise

- Opioid analgesia or sedatives: [1]
  - risk of in-hospital cardiopulmonary and respiratory arrest:
    - medical: adjusted OR: opioids = 2.24; sedatives = 1.80; both = 3.83
    - surgical: adjusted OR: opioids = 1.12; sedatives = 1.58; both = 2.34
- Obstructive sleep apnea [2]
  - Increased risk of post-operative respiratory failure (OR 2.42, CI 1.53-3.84, p = 0.0002)
  - ICU transfer more frequent (OR = 2.46, CI 1.29-4.68, p = 0.006)
- Underlying chronic respiratory & cardiac disease [3]: patients with COPD - increased risk for postop respiratory failure (5.5% versus 1.2%, $p < 0.0001$)[4]

[1]Izrailtyan, I. *PLoS ONE* 2018; 13: 1
[2]Hai, F. *J Clin Anesthesia* 2014; 26: 591
[3]Weingarten T. *Anesth Analg* 2015; 121:422
[4]Gupta H. *Chest* 2013;143:1599

Opioid-Induced Respiratory Depression

- ↓ respiratory drive (direct increase in activity of brainstem inhibitory neurons), ↓ ventilatory response to hypoxia & hypercarbia, ↓ LOC (sedation), ↓ supraglottic airway tone
- No consensus definition of OIRD: naloxone reversal, bradypnea; hypoxemia: incidence 0.1 – 23.7%
- Risk factors: age > 65, ASA III & IV, OSA, COPD, cardiac disease

[1]Gupta, K. *Current Opinion in Anaesthesiology* 2018; 31: 110

Postoperative Opioid-Induced Respiratory Depression

- closed malpractice claims analysis (1990-2009)
  - mean age 50 ± 17.7 yr
  - ASA 1-2: 63%
  - OSA dx: 16% & high risk of OSA: 9%
- 55% death & 22% permanent brain damage
- 88% of events occurred ≤ 24 hrs after admission
- 78% of events ≤ 2 hrs since last nursing check
- 33% non-telemetric oximetry
- monitoring probably (47%) or possibly (50%) would have prevented event

Lee L. An*esthesiology 2015*, *122*, 659

PRODIGY: PRediction of Opioid-induced respiratory Depression In patients monitored by capnoGraphY

- Respiratory depression (RD): $ETCO_2$ ≤15 or ≥ 60mmHg for ≥ 3min, RR ≤ 5 breaths for ≥ 3min, SpO_2 ≤ 85% for ≥3 min, apnea > 30 sec, or a respiratory opioid-related adverse event
- RD: 41.4% (n = 1,496 patients)
- positive predictors of RD ($p \leq 0.05$) by univariate analysis: age, male sex, major organ failure, chronic heart failure or cardiac disease, coronary artery disease, COPD or pulmonary disease, pneumonia, Type II DM, hypertension, kidney failure, and opioid naivety
- **Risk prediction score: age, male sex, sleep disorder, hypertension, and opioid naivety**
- Risk prediction tool predicted 76% of patients with confirmed respiratory depression

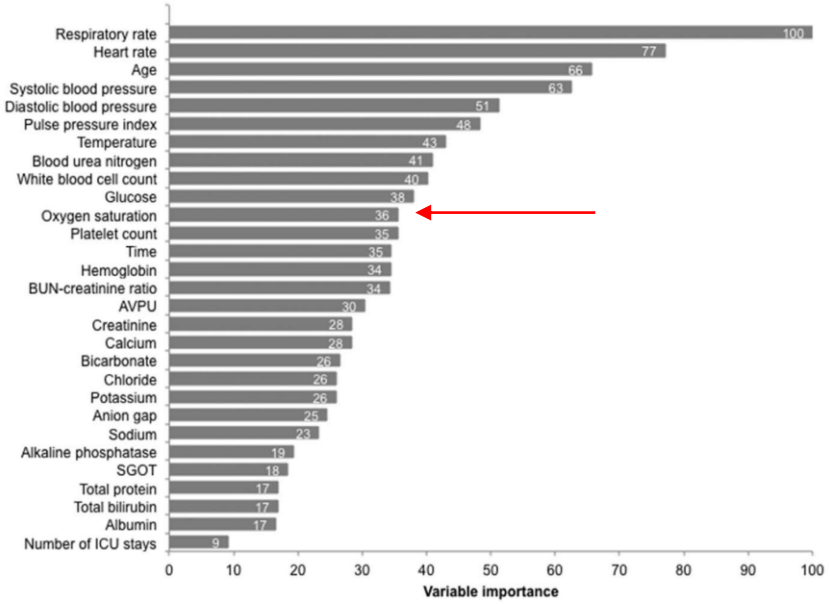
Khanna A. *Crit Care Med* 2019; 47: A36

Predicting Respiratory Compromise: Real Time Prediction: Respiratory Rate

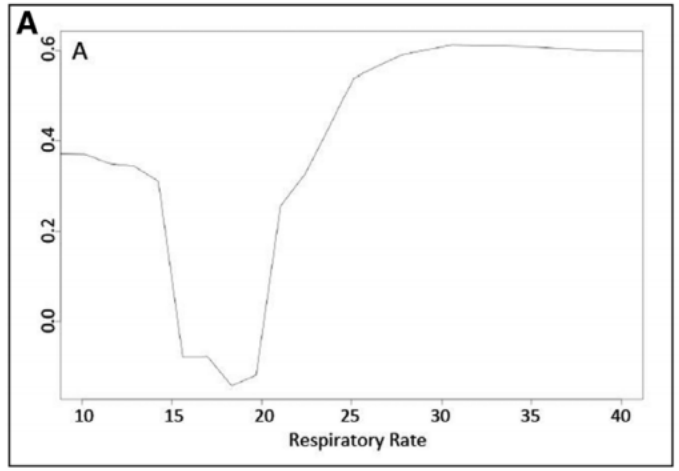
- R… predictor of in-H… CU [1]

algorithm learns from examples (features & labels) rather than being programmed with rules [3]

- Machine learning on large retrospective database (n = 270,000): RR most important variable to predict clinical deterioration in GCU [2]



Combined outcome cardiac arrest, ICU transfer or death



[1]Fieselmann J. *J Gen Int Med* 1993; 8: 354
[2]Churpek M. *Crit Care Med* 2016; 44:368
[3]Rajkomar A. *N Engl J Med.* 2019; 380:1347

Predicting Respiratory Compromise
Respiratory Rate: Neglected Vital Sign

- RR affected by multiple physiologic derangements:
  - Respiratory depression
  - Hypoxemia
  - Reduced pulmonary compliance
  - Metabolic acidosis
  - Respiratory muscle failure
- RR is manually counted, frequently not documented [1,2] & inaccurately measured [3,4]

[1]Elliott, M. *Int Archives of Nursing and Health Care* 2017; 2: 2
[2]Hogan J. *British Journal of Nursing* 2006; 15: 489
[3]Kriss M. *Chest* 2012; 143: 1740
[4]Badawy J. *BMJ Qual Saf* 2017;26:832

Predicting Respiratory Compromise: Early Warning System (EWS) Scores

	3	2	1	0	1	2	3
Systolic BP (mmHg)	<70	71-80	81-100	101-199		>200	
Heart rate (bpm)		<40	41-50	51-100	101-110	111-129	>130
Respiratory rate		<9		9-14	15-20	21-29	>30
Temperature (°C)		<35		35-38.4		>38.5	
AVPU score/ RASS score				**A**lert +3 to 0	Reacting to **V**oice -1 to -3	Reacting to **P**ain -4	**U**nresponsive -5

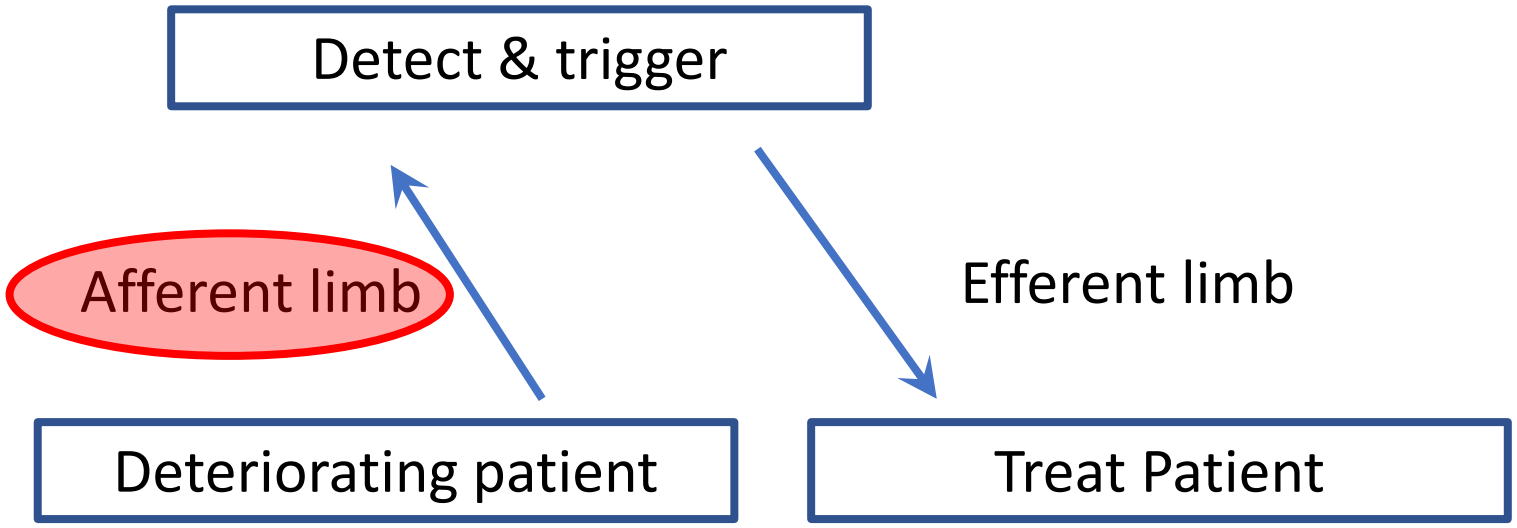
MEWS (Modified Early Warning Score) [1]

- EWS: multiple parameter scores are better than single physiologic variables [2] & have strong predictive value of death & cardiac arrest within 48 hours [3]
- Effects on health outcomes of manually collected & triggered EWS is uncertain [3]
- Automated VS collection and trigger may improve incidence of cardiac arrest & mortality [4,5]
- No data regarding false positives (false alarms)

[1]Subbe C. *QJM : Monthly J Assoc of Physicians* 2001; 94: 521
[2]Jarvis S. *Resuscitation* 2015;87:75
[3]Smith M. *Ann Am Thor Soc* 2014; 11: 1454
[4]Kollef MH. *J Hosp Med* 2014; 9:424
[5]Subbe CP. *Crit Care* 2017; 21:1

Current State of GCU Monitoring

- Intermittent vital signs (q 4 hrs @ 5 min/VS = only 2% monitored)
- Early warning system triggered by one or more abnormal physiologic parameter



Taenzer A. *Crit Care Clin* 2018. 34:189

Changing Landscape of ICU Monitoring

- Universal adoption of EHR
- Advances in physiologic sens
- Mobile technologies
- Artificial intelligence/decisior

Bates D. *BMJ Qual Safety* 2015; 24:1

Bonnici T. *Clin Med J R Coll Physicians London* 2013; 13:252

Rajkomar A. *N Engl J Med.* 2019; 380:1347

Topol E. *Deep Medicine: How Artificial Intelligence Can Make Healthcare Human Again* 2019; Basic Books

Continuous Pulse Oximetry: Evidence

- Largest RCT (>20,000 OR/PACU patients): incidence of hypoxemia (SpO_2 < 90%): 7.9% monitored with pulse oximetry vs. 0.4% in patients without oximetry [1]
- Postoperative hypoxemia is common, persistent and unrecognized: 37% of patients had at least one SpO_2 < 90% for ≥ 1 h; nurses failed to record 90% of prolonged hypoxemic episodes [2]
- Continuous pulse oximetry in postoperative orthopedic patients (n=5,959): before/after study (Dartmouth) [3]
  - Rescue events ↓ from 3.4 (1.89–4.85) to 1.2 (0.53–1.88)/1,000 patient discharges (p=0.01)
  - ICU transfers ↓ from 5.6 (3.7–7.4) to 2.9 (1.4–4.3) /1,000 patient days (p=0.02)
  - 2 comparison units had no change in rescue events or ICU transfers [3]

[1]Moller J. *Anesthesiology* 1993; 78: 445
[2]Sun Z. *Anesth Analg* 2015; 121: 709
[3] Taenzer A. *Anesthesiology* 2010; 112: 282

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Continuous Pulse Oximetry: Evidence

- RCT (n=1219) cardiothoracic unit: Routine CPOX was not associated with overall decreased transfer to ICU, mortality, or total estimated costs of hospitalization [1]
- Cochrane meta-analysis: *existing evidence demonstrates that pulse oximetry reduces the incidence of hypoxemia but does not improve overall patient outcomes and does not reduce morbidity or mortality* [2]

[1] Ochroch E. *Anesth Analg* 2006; 102: 868
[2] Pedersen T. *Cochrane Database Syst Rev* 2014; 2014;(3)

Pulse Oximetry: Limitations

- Inability to measure ventilation → false sense of security
- Patience acceptance
- Alarm threshold – GCU is not OR
- Pediatric bronchiolitis: studies demonstrate limited benefit of CPOX with ↑LOS [1]

[1]Quinonez R (2017). *BMJ (Online)* 2017; 358: j3850

Continuous Capnography: Evidence

- Pooled data from 3 studies:
  - Post-operative respiratory depression (PORD = O_2 desaturation, bradypnea, or hypercarbia): continuous capnography identified 11.5% vs. 2.8% by continuous oximetry, $p < 0.00001$
  - Recognition of PORD: OR = 5.83 (3.54-9.63) $p < 0.00001$
- No studies examined the impact of continuous capnography on reducing rescue team activation, ICU transfers or mortality

Lam T. *Anesth Analg* 2017; 125: 2019

Alternative Measures of Ventilation (other than capnography)

- Transcutaneous CO_2
- Airflow detector
- Impedance plethysmography
- Bioacoustic sensor
- Piezoelectric sensor

Vincent J. *Eur J Anaesthesiology* 2018; 35: 325

Procedural Sedation

- Relief of pain & anxiety allowing patients to tolerate uncomfortable procedures
- Facilitation of procedures in which immobility may be necessary
- Anesthesia delivered outside the OR is increasing (from 2003: 11% → 2015: 30%) [1]
- ASA closed-claims database: [2]
  - respiratory mechanism more common outside the OR (44% vs. 20%)
  - outside the OR: double the risk of death from respiratory-related complications

[1]Ferrari L. *Current Opinion in Anaesthesiology* 2015; 28: 439
[2]Metzner J. *Current Opinion in Anaesthesiology* 2009; 22: 502

Continuum of Depth of Sedation

	Minimal sedation	Moderate sedation	Deep sedation	General sedation
Responsiveness	normal response to verbal stimuli	purposeful response to verbal or tactile stimuli	purposeful response following repeated or painful stimuli	unarousable even with painful stimuli
Airway	unaffected	no intervention required	intervention may be required	intervention often required
Spontaneous ventilation	unaffected	adequate	may be inadequate	frequently inadequate
Cardiovascular function	unaffected	usually maintained	usually maintained	may be impaired

Adapted from *American Society of Anesthesiologists*, 2014

Deep sedation occurred in 68% of patients (26% of q 3 min assessments) given IV meperidine & midazolam with intent of moderate sedation

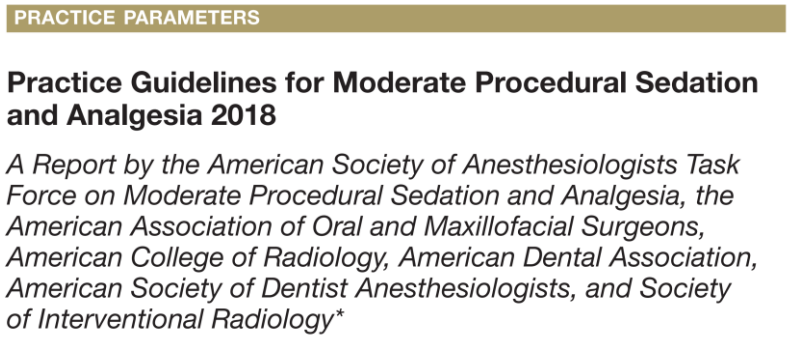
Patel S. *Am J Gastroenterology* 2005; 100: 2689

Procedural Sedation & Capnography: Evidence

- Meta-analysis (6 studies): capnography reduces hypoxemic episodes: RR = 0.71 (0.56–0.91), p = 0.02. No evidence that capnography affected other outcomes, including assisted ventilation [1]
- Meta-analysis (13 studies): capnography reduces severe hypoxemia (≤ 85%) (OR = 0.55, 0.38-0.78) and need for assisted ventilation (OR = 0.47, 0.23-0.95) [2]
- Meta-analysis of capnography & procedural sedation in ER (only 3 studies, n = 1,272): lack of convincing evidence that addition of capnography to standard monitoring in procedural sedation reduces the rate of oxygen desaturation or airway intervention [3]

[1]Conway, A. *Anaesthesia* 2016; 71: 450
[2]Saunders R. *BMJ Open*. 2017;7:1
[3]Wall B. *Cochrane Database of Systematic Reviews* 2017, Issue 3. Art. No.: CD010698

Clinical Practice Guideline: ASA


PRACTICE PARAMETERS

Practice Guidelines for Moderate Procedural Sedation and Analgesia 2018

*A Report by the American Society of Anesthesiologists Task Force on Moderate Procedural Sedation and Analgesia, the American Association of Oral and Maxillofacial Surgeons, American College of Radiology, American Dental Association, American Society of Dentist Anesthesiologists, and Society of Interventional Radiology**

- Continuously^ monitor all patients by pulse oximetry with appropriate alarms
- Continually* monitor ventilatory function by observation
- Continually monitor ventilatory function with capnography unless precluded or invalidated by the nature of the patient, procedure, or equipment
- Uncooperative patients: capnography after moderate sedation achieved

^continuous: prolonged without any interruption at any time
**continual: repeated regularly and frequently in steady rapid succession*

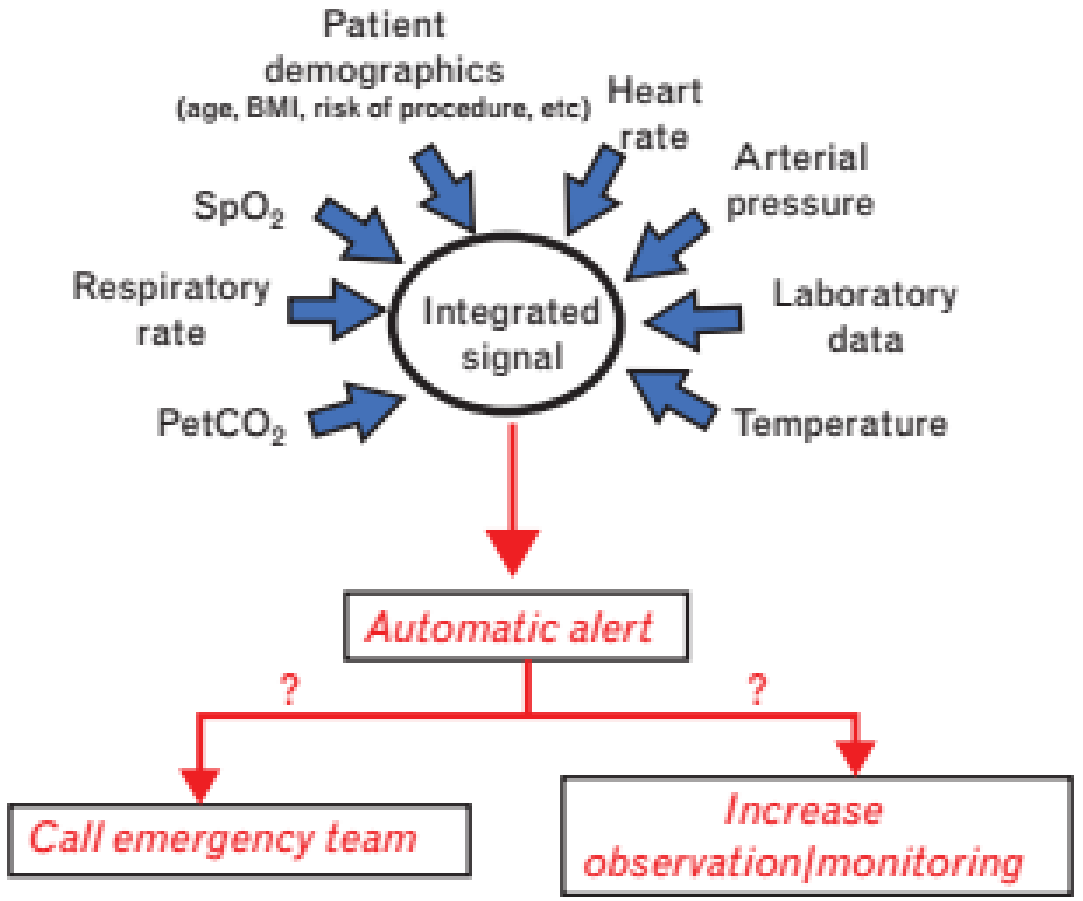
Connis R. *Anesthesiology* 2018; 128: 437

False Alarms and Alarm Fatigue

- Alarm fatigue = *"failure to recognize & respond to true alarms that require intervention as a result of high occurrence of alarms"*
- The Joint Commission issued a 2013 Sentinel Event Alert implicating alarm fatigue in 98 adverse events, including 80 deaths [1]
- Tradeoff of sensitivity and false alarm
- Appropriate threshold: Dartmouth: low SpO_2 threshold = 85%
- Notification delay (low SpO_2 threshold of 88% and 15-sec delay decreases alarms > 85%) [2]
- Role for machine learning

[1] *The Joint Commission Sentinel Event Alert*. 2013; 50: 1
[2] Welch J. *Biomedical Instrumentation & Technology* 2011; 45: 46

Integrated General Care Unit Monitoring: The Future



Vincent JL. *Eur J Anaesthesiol* 2018;35:325

Monitoring in General Care Units: Summary

- Respiratory compromise in GCU is common and has serious consequences
- Distinct pathophysiologic categories & trajectories of respiratory compromise
- Clinical outcome evidence for routine continuous oximetry & capnography in GCU is weak
- Capnography or other measure of ventilation is recommended during procedural sedation
- Technology & machine learning will improve GCU monitoring
- Need to be aware of false alarms & alarm fatigue