

# Big Data in Postoperative Monitoring – What's Changing?

Ashish K.Khanna MD.,FCCP.,FCCM

Associate Professor & Associate Section Head for Research

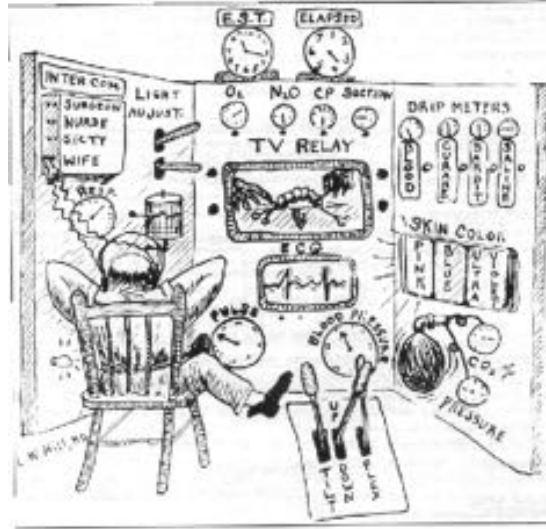
Department of Anesthesiology, Section on Critical Care Medicine



## Disclosures






- Medtronic
- Edwards Lifesciences
- FAER “A randomized pilot trial of continuous postoperative hemodynamic and saturation monitoring”

# The intraoperative period has become safer...



3

# The postoperative period ...(not yet)?

-  Death due to diseases of the heart (CDC)
-  Death due to malignant neoplasms (CDC)
-  Death within 30 days of admission for surgery (NIS) 
-  Death due to cerebrovascular diseases (CDC)

4

## Postoperative complications occur on the general care floor

- **Ward hypotension and hypoxemia**
  - Common, profound, and prolonged
  - Cannot be reliably predicted
- **Acute respiratory events**
  - In-hospital mortality of approximately 40%
- **Heart attacks occur postoperatively**
  - 94% within two days
  - 50% of deaths during initial hospitalization

Andersen, et al. Resuscitation 2016

5

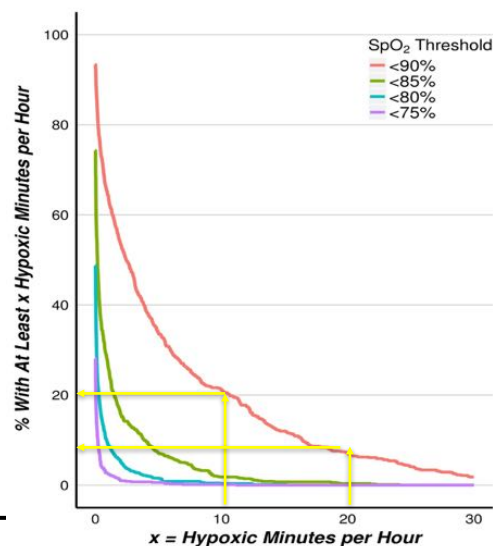
Wake Forest<sup>®</sup>  
School of Medicine

## Postoperative hypoxemia

Minutes hypoxemia per hour

Blinded ward monitoring

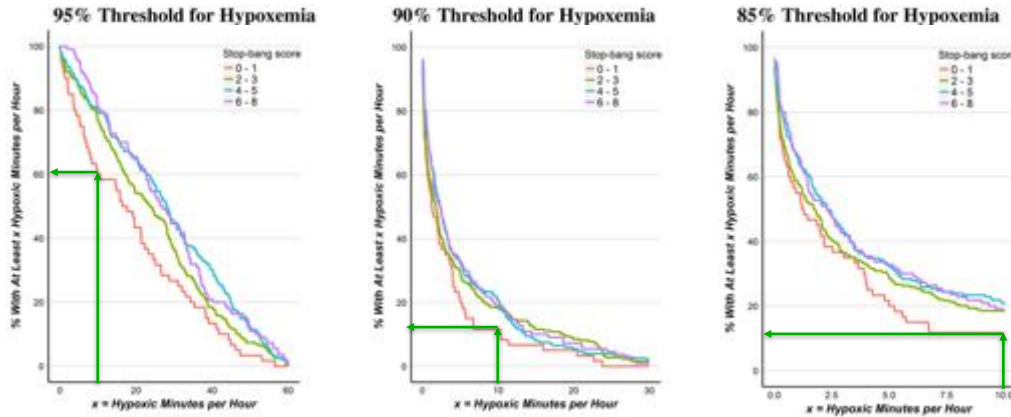
≈850 non-cardiac surgical patients



Sun, et al. A&A 2015

Wake Forest<sup>®</sup>  
School of Medicine

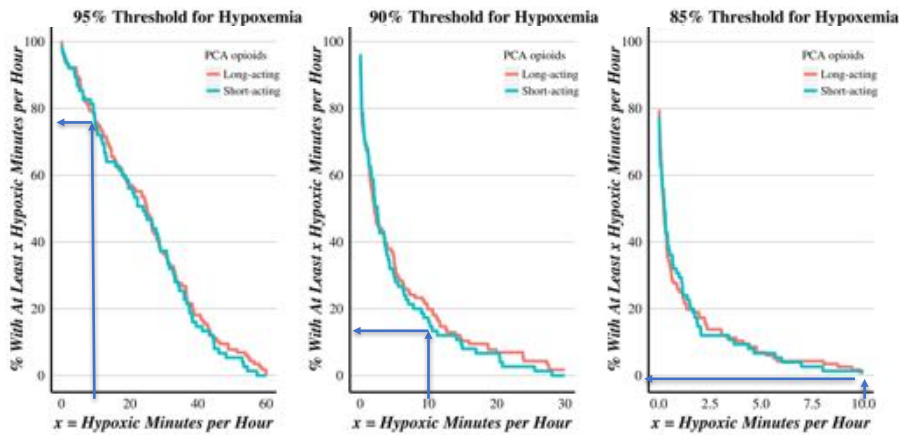
## Postoperative hypoxemia – common, undetected & difficult to predict (STOP-BANG scores)



Khanna AK, et al. BJA 2016

7

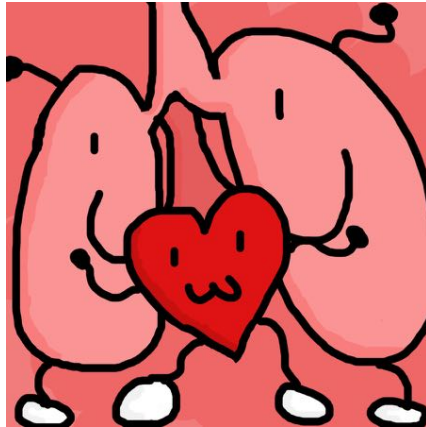
## Postoperative hypoxemia – common, undetected & difficult to predict (long vs short acting opioids)



Belcher AW, Khanna AK, et al. A&A 2016

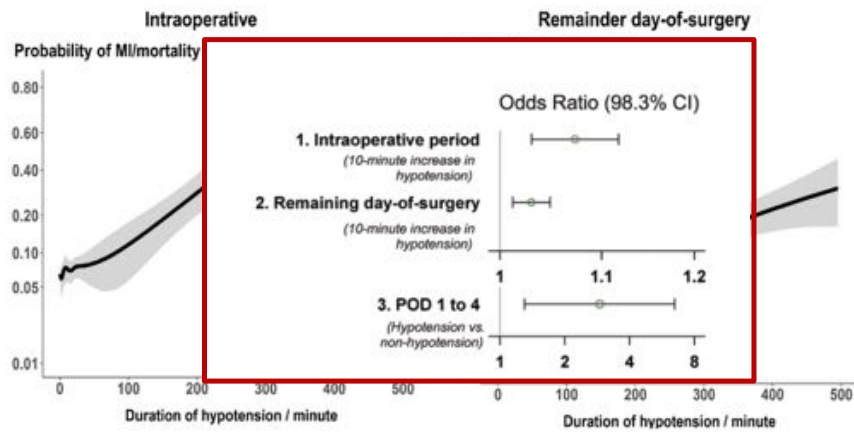
8

# The heart is not too far away from the lungs...

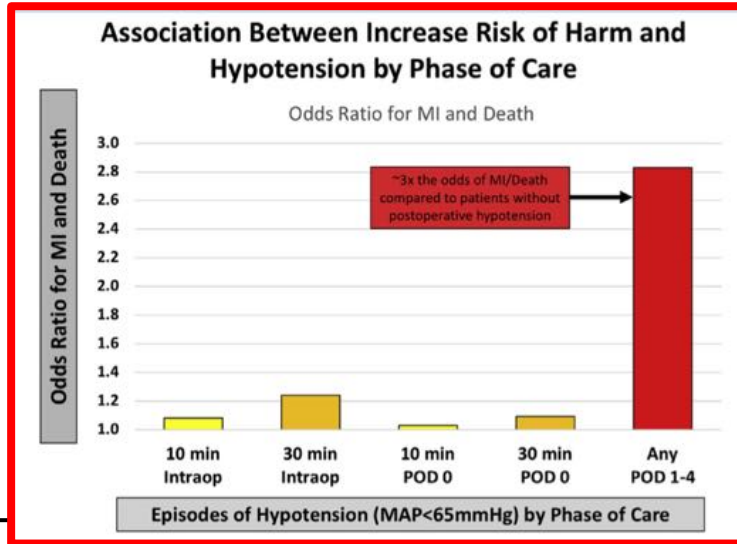


- ✓ etCO2
- ✓ RR
- ✓ SpO2
- ✓ HR
- ✓ ? Blood Pressure

# Postoperative Hypotension Matters!!



# Postoperative Hypotension Matters!!



Wake Forest®  
School of Medicine

# Postoperative Hypotension & adverse events

Khanna AK et al. (Unpublished data)

Adverse event	Overall	Post-operative hypotension			
		MAP≤55-mmHg	MAP≤65-mmHg	MAP≤75-mmHg	MAP>75-mmHg
	Number of patients	Number of patients	Number of patients	Number of patients	Number of patients
30-day MACCE	66,591	2,332	14,976	42,214	24,377
30-day mortality	67,968	2,411	15,368	43,151	24,817
90-day mortality	67,968	2,411	15,368	43,151	24,817
30-day AMI	67,317	2,372	15,170	42,692	24,625
30-day AIS	67,200	2,381	15,178	42,658	24,542
7-day AKI (II/III)	67,845	2,360	15,214	42,965	24,880
30-day readmission	67,580	2,387	15,233	42,872	24,708

Wake Forest®  
School of Medicine

# The '4am phenomenon'...

What (really) happens prior to a "CODE BLUE"?



Khanna AK et al. Crit Care 2019

Wake Forest School of Medicine

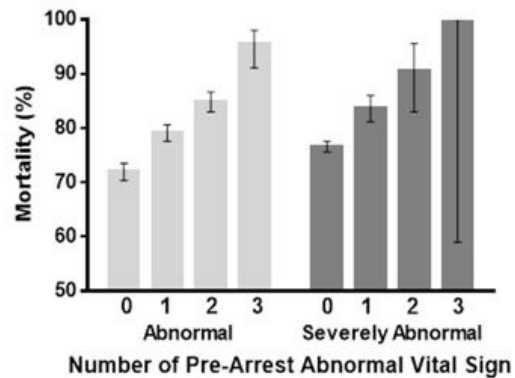


## What's changing?

Wake Forest School of Medicine

## How about monitoring?

- 60% patients had at least one abnormal vital sign 1–4 hours before cardiorespiratory arrest
- Step-wise increase in mortality with increasing number of abnormal vital signs



Andersen, et al. Resuscitation 2016

15

Wake Forest<sup>®</sup>  
School of Medicine

## Better (**smarter**) monitoring may be an answer ?

PAIN MEDICINE

### Postoperative Opioid-induced Respiratory Depression

*A Closed Claims Analysis*

Lorri A. Lee, M.D., Robert A. Caplan, M.D., Linda S. Stephens, Ph.D., Karen L. Posner, Ph.D.,  
Gregory W. Terman, M.D., Ph.D., Terri Voepel-Lewis, Ph.D., R.N., Karen B. Domino, M.D., M.P.H.

- ✓ **97% preventable – better monitoring and response**
- ✓ **42% - 2hr of last check**
- ✓ **Multiple prescribers**
- ✓ **Non-opioid sedatives**

16

Wake Forest<sup>®</sup>  
School of Medicine



# Monitoring and survival

	Total	ICU	Monitored Ward	Unmonitored Ward	P-Value*
No. of hospitals	445	445	445	445	
Unadjusted event rate, mean (SD)	0.580 (0.325)	0.337 (0.215)	0.109 (0.079)	0.134 (0.098)	<0.0001
Unadjusted survival rate, mean (SD)	0.173 (0.079)	0.162 (0.096)	0.231 (0.171)	0.141 (0.122)	<0.0001
Adjusted survival rate, mean (SD)	0.144 (0.032)	0.140 (0.037)	0.193 (0.074)	0.106 (0.037)	<0.0001

Adjusted survival rate		
ICU	Monitored Ward	Unmonitored Ward
0.140	0.193	0.106

Perman, et al. JAHA 2016

Wake Forest School of Medicine



The '4am' phenomenon

Khanna AK et al. Crit Care 2019

Wake Forest School of Medicine

## Continuous (**smarter**) monitoring for all?

- Better monitoring?
  - Who to monitor?
  - What to monitor?
  - How to monitor?
  - Data reliability/validity?
  - **Alarm fatigue**
  - **Convert GCF ->ICU?**
- ➔
- Terabytes of data
  - Handling alarms
  - Prediction of risk

19

## Alarm Fatigue – and the case for AI based Optimization



Simulate

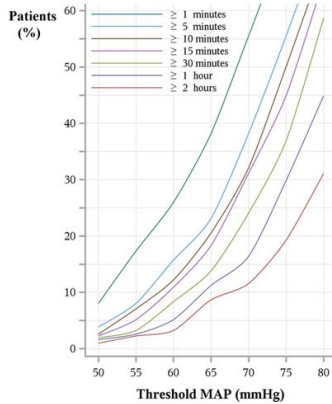
**Low Threshold**

	81	83	85	87
0	0.88	1.60	3.54	8.42
60	0.44	0.87	1.96	4.74
90	0.29	0.56	1.31	3.36
120	0.18	0.41	1.00	2.59

Optimize

Parameter	Alarms/ Patient/ Day
SpO2	1.17
Cardiac Rate	0.31
Resp Rate	0.87
Continuous BP	0.67
<b>TOTAL</b>	<b>3.04</b>

## Postoperative Hypotension – common & undetected



**Patients Missed by Routine Assessments among Those Detected by Continuous Monitoring**

MAP Threshold for Hypotension (mm Hg)	N, Detected by Continuous Monitoring, N (%)*	No. Missed by Routine Assessments/ No. Detected by Continuous Monitoring	Proportion (95% CI)	N, Detected by Routine Vital-sign Assessments, N (%)†
< 50	3 (2%)	67	95% (41, 100)	4 (1%)
< 55	16 (5%)	1216	75% (48, 92)	12 (4%)
< 60	34 (11%)	1824	52% (36, 70)	26 (8%)
< 65	57 (18%)	2757	47% (34, 61)	44 (14%)
< 70	97 (31%)	2697	27% (18, 37)	131 (42%)
< 75	149 (45%)	1414	17% (8, 30)	232 (68%)
< 80	204 (60%)	6254	2.9% (1.1, 6.3)	258 (82%)

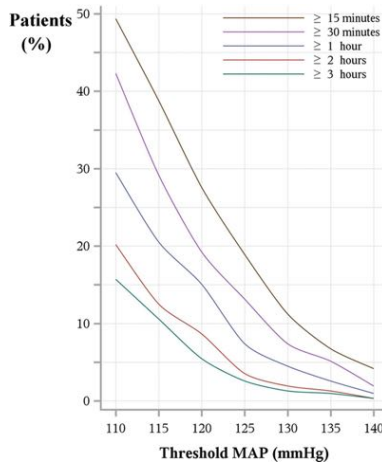
\*Continuous monitor detected at least one contiguous episode (without gap greater than or equal to 5 min) for at least 15 min below threshold. †Defined by single measurements.

**Spot checks missed about 50% of episodes of MAP<65mmHg detected by continuous monitoring**

Turan A, Khanna AK et al. Anesthesiology 2019



## Postoperative Hypertension – common & undetected



**Patients Missed by Routine Assessments among Those Detected by Continuous Monitoring**

MAP Threshold for Hypertension (mm Hg)	Detected by Continuous Monitoring, N (%)*	No. Missed by Routine Assessments/ No. Detected by Continuous Monitoring	Proportion (95% CI)	Detected by Routine Vital-sign Assessments, N (%)†
> 110	132 (42%)	95/132	73% (64, 80)	44 (14%)
> 115	91 (29%)	72/91	79% (68, 87)	21 (7%)
> 120	60 (19%)	52/60	87% (75, 94)	10 (3%)
> 125	41 (13%)	40/41	98% (87, 100)	2 (0.6%)
> 130	23 (7%)	22/23	96% (75, 100)	2 (0.6%)
> 135	16 (5%)	15/16	100% (75, 100)	1 (0.3%)
> 140	6 (2%)	6/6	100% (64, 100)	1 (0.3%)

\*Continuous monitor detected at least one contiguous episode (without gap greater than or equal to 5 min) for at least 30 min above threshold. †Defined by single measurements.

**Spot checks missed about 75% of episodes of MAP>110mmHg detected by continuous monitoring**

Turan A, Khanna AK et al. Anesthesiology 2019




## Preventing Respiratory Depression

Daniel I. Sessler, M.D.

**L**EE *et al*<sup>1</sup> evaluated closed malpractice claims related to respiratory depression. They identified 52 closed claims over 20 yr in about a third of covered anesthesiologists, which corresponds very roughly to 14 closed claims per year for all anesthesiologists nationwide among perhaps 75 million cases. Three-quarters of the patients died or were left with severe brain damage; half resulted in settlement payments, with the median being \$217,000 (interquartile range: \$50,000 to \$604,000). We know that only a small fraction of adverse outcomes results in malpractice claims. It is thus apparent that postoperative respiratory events resulting in death or serious injury occur at a concerning rate.


Most patients whose closed claims resulted from respiratory events were given opioids, nearly half by at least two sources—often prescribed by different physicians, and nearly half had a respiratory



Case reviewers judged that 57% of claims probably or possibly could have been prevented by better monitoring. More intense conventional monitoring probably is not the answer though. Hypoxemia in postoperative inpatients is common, acute, and prolonged.<sup>2</sup> Furthermore, even serious and persistent hypoxemia is unrecognized by nurses in 80% of consecutive inpatient data. (Department of Outcomes Research, Cleveland Clinic, December 2014). That a full quarter of the respiratory events in the review of Lee *et al*<sup>1</sup> occurred within 15 min of a nursing evaluation shows how often the current system fails.

So what can we do? Continuous monitoring is perhaps the obvious way to prevent catastrophic postoperative respiratory events. It is tempting to target continuous monitoring to high-risk patients, such as those who have a history of sleep apnea or are obese. The difficulty is that even the best produc-

*“It is likely that many catastrophic respiratory events could be prevented by continuous . . . monitoring. However, major trials are needed to determine what should be monitored and how.”*



# Can we predict risk of respiratory depression?

ClinicalTrials.gov

A service of the U.S. National Institutes of Health

[Try our beta test site](#)

Example: "Heart attack" AND "Los Angeles"

Search for studies:

[Advanced Search](#) | [Help](#) | [Studies by 1](#)

Find Studies
About Clinical Studies
Submit Studies
Resources
About This Site

Home > Find Studies > Search Results > Study Record Detail

Trial record 1 of 20 for: PRODIGY

[Previous Study](#) | [Return to List](#) | [Next Study](#)

**P**Rediction of Opioid-induced Respiratory Depression in Patients Monitored by capnoGraphY (PRODIGY)

## PRODIGY Model Derivation – Multivariate Predictors

Clinical Characteristic	Estimate	Standard Error	OR	Pr >  t	Points if Clinical Characteristic = 'Yes'
AGE (<60)	ref	.	.	.	0
AGE (≥60 - <70)	0.797	0.145	2.218	<.001	8
AGE (≥70 - <80)	1.237	0.180	3.445	<.001	12
<b>AGE (≥80)</b>	1.552	0.363	4.719	<.001	16
<b>Sex (M)</b>	0.772	0.128	2.163	<.001	8
<b>Opioid Naïve</b>	0.290	0.165	1.337	.079	3
<b>Sleep Disorders</b>	0.461	0.199	1.585	.021	5
<b>Heart Failure</b>	0.735	0.401	2.085	.067	7
					Sum = PRODIGY Score

**619 patients with at least one RD episode ( 44.8% )**

25

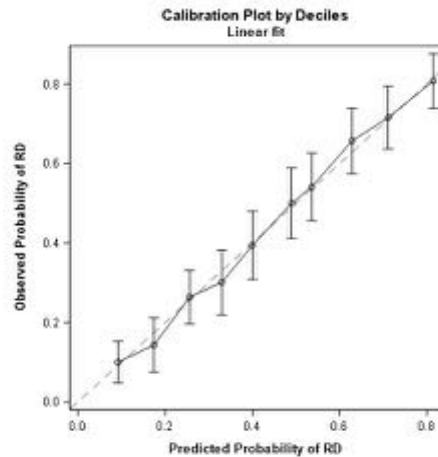
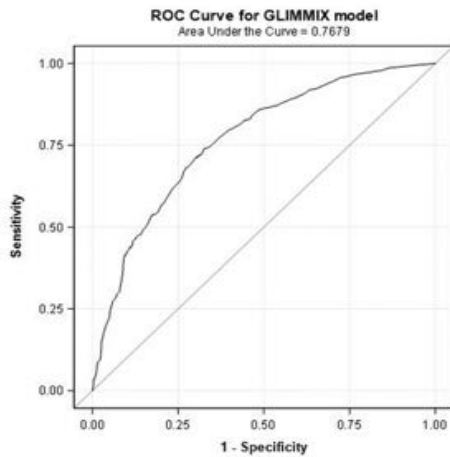
## PRODIGY Model Derivation – Multivariate Predictors

	Low Risk	Intermediate Risk	High Risk	p value
PRODIGY Score	<8 points	8 – 14 points	≥15 points	
Pts in Risk Category	359	474	471	
Pts with RD in Risk Category	84	195	300	
% Pts with RD in Risk Category	23%	41%	64%	<.001
Sensitivity	---	0.85	0.52	
Specificity	---	0.38	0.76	
OR (95% CI, P value)	OR <sub>IL</sub> = 2.29 (1.69–3.11, P<.001) OR <sub>HL</sub> = 5.74 (4.22–7.82, P<.001)	OR <sub>HI</sub> = 2.5 (1.99–3.26, P<.001)		

**619 patients with at least one RD episode ( 44.8% )**

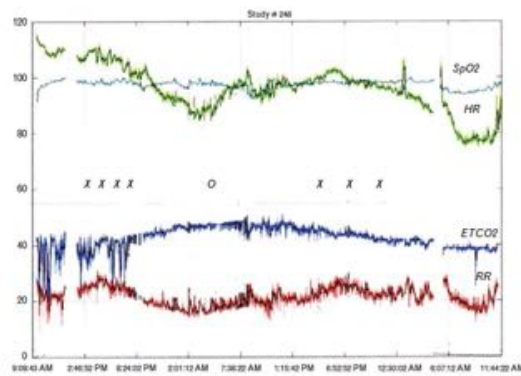
26

# PRODIGY Model Accuracy

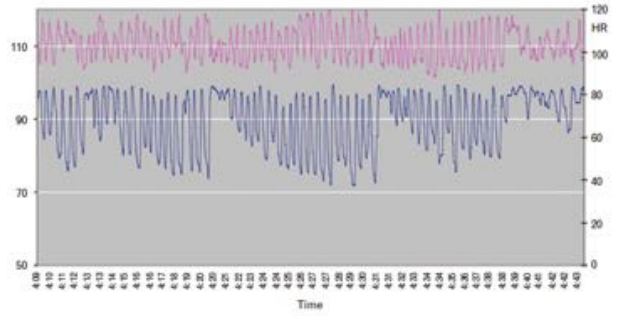
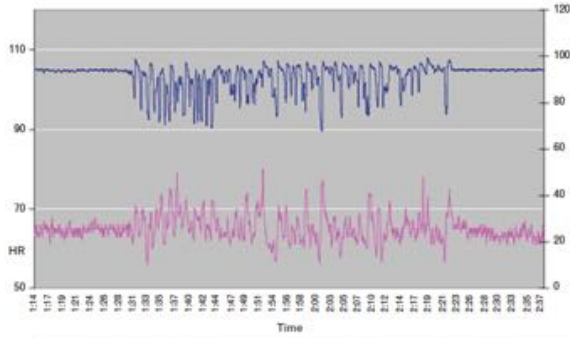


\*Statistical significance may be linked to other medical characteristics

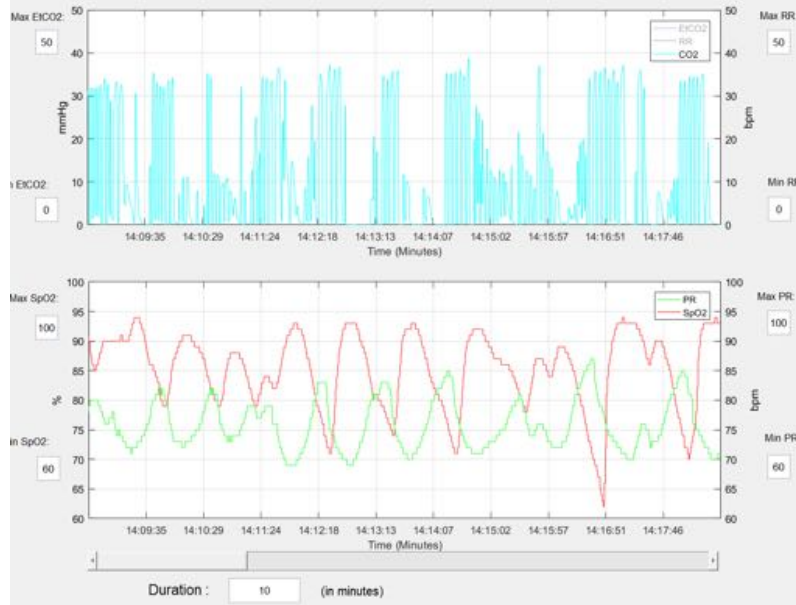
# All about pattern detection!

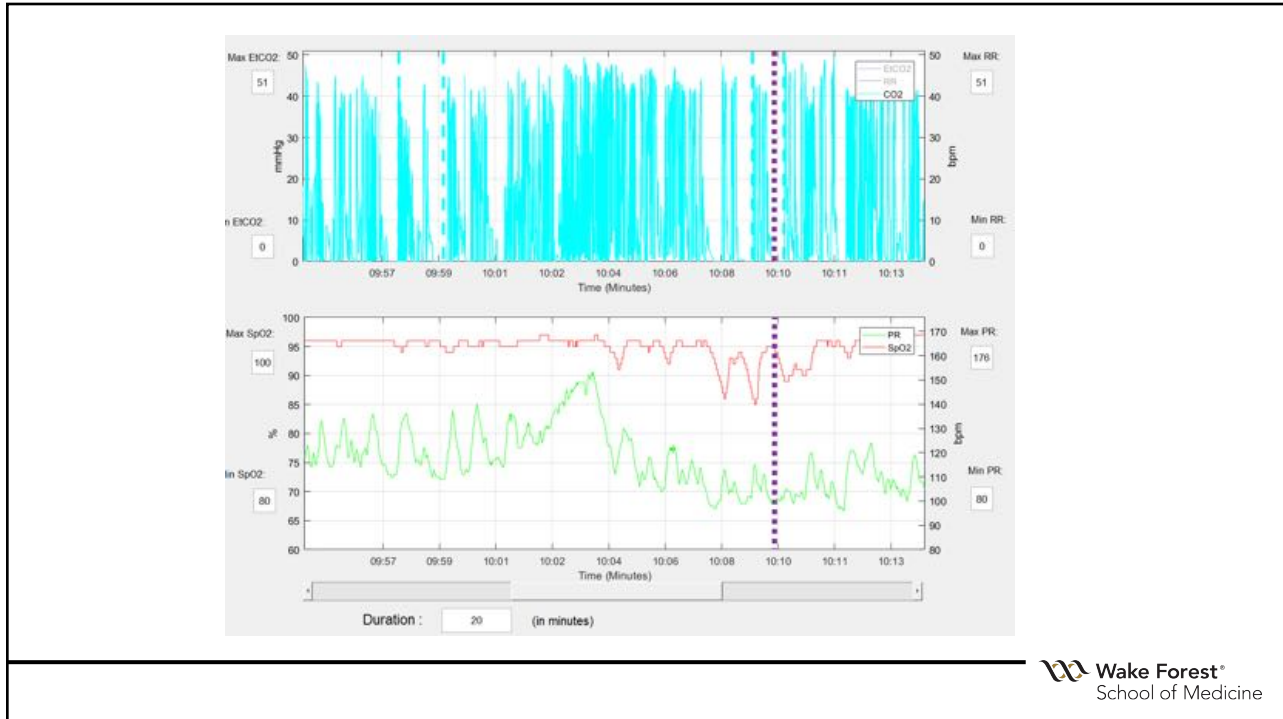


# All about pattern detection!

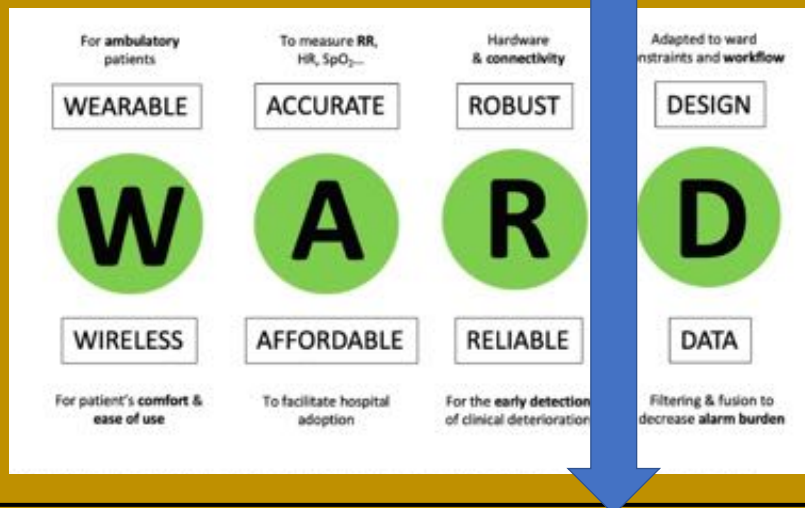


29





# The (big data) challenge... Role for AI





33 Wake Forest®  
School of Medicine

Difficult to predict

Smart monitoring

Continuous monitoring

# Big Data in Postoperative Monitoring – What's Changing?

Wake Forest®  
School of Medicine

Scoring systems  
 Proactive RRT  
 Alarm fatigue & artifact  
 Central platforms & AI  
 Culture change

# Big Data in Postoperative Monitoring – What's Changing?







### VENTURE CAFÉ WINSTON-SALEM

**BY THE NUMBERS, MAY 2017-2019**

<p> <b>19,569</b> connection hours</p> <p> <b>6,837</b> subscribers on the email list</p> <p><b>189</b> organizations represented in programming</p>	<p><b>14,374</b> total visits </p> <p> <b>15</b> investor meetings</p> <p><b>100,000+</b> Facebook reach </p>
--	--

**Attendee Industries**

EDUCATION	ARTS	COMMUNICATIONS	MOBILITY
LOGISTICS	LEGAL	AGRICULTURE	SCIENCE
SOFTWARE	DESIGN	SOCIAL SERVICE	FASHION
AEROSPACE	FOOD	ENVIRONMENT	SAFETY
HARDWARE	AI	CONSTRUCTION	WELLNESS
HOSPITALITY	ENERGY	MANUFACTURING	FINANCE
			SPORTS

<https://w>



Several  
'critical big  
data points'  
at home?



Continuous  
smarter  
parenting!



## Big Data in Postoperative Monitoring – What's Changing?

Ashish K.Khanna MD.,FCCP.,FCCM

Associate Professor & Associate Section Head for Research

Department of Anesthesiology, Section on Critical Care Medicine