Update on Continuous Respiratory Monitoring Options for Low Acuity Settings

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Society for Anesthesia and Sleep Medicine
Oct 20, 2016, Chicago IL

Disclosure

- Consultant; Covidien - Medtronic Respiratory Monitoring Solutions

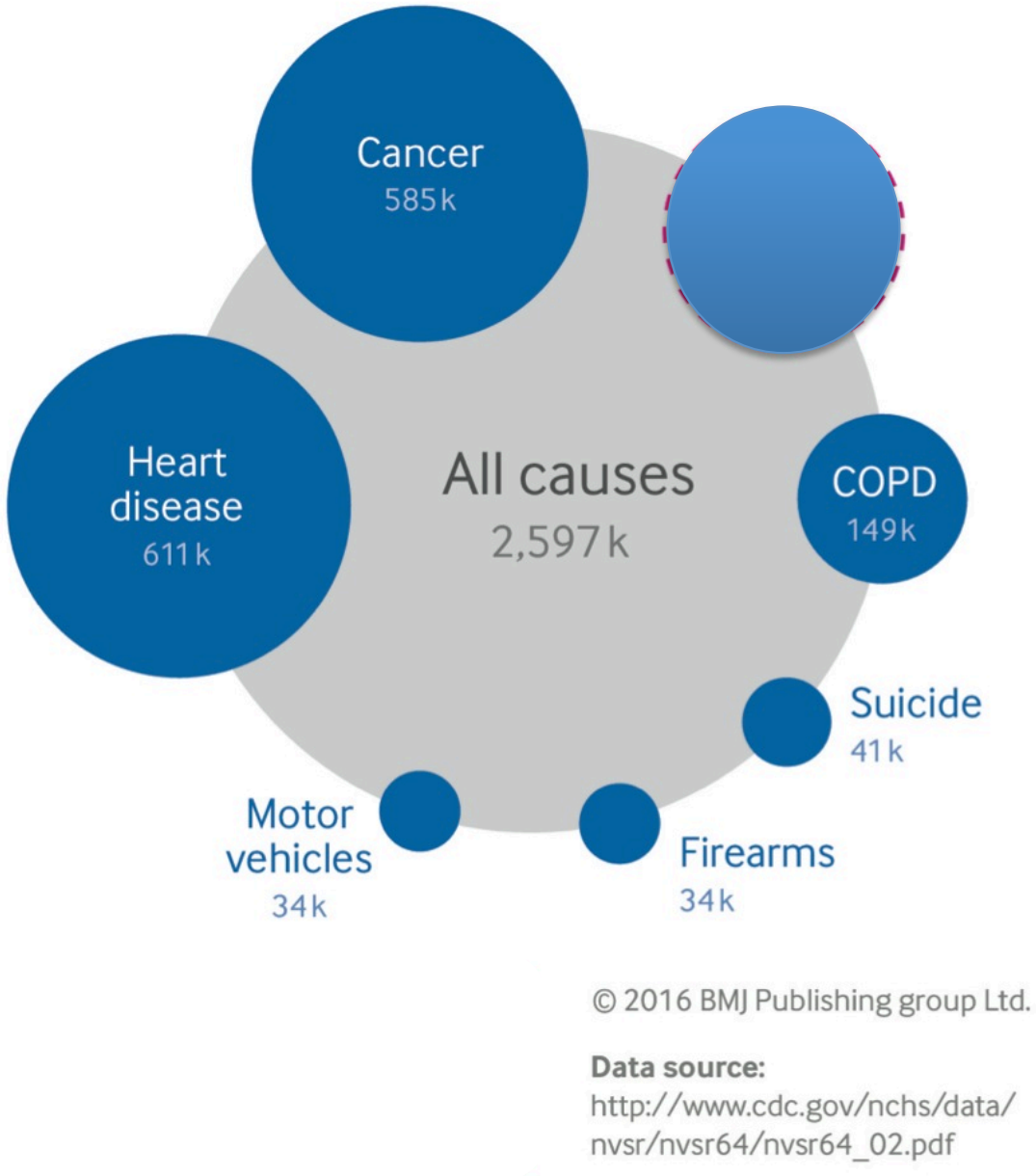
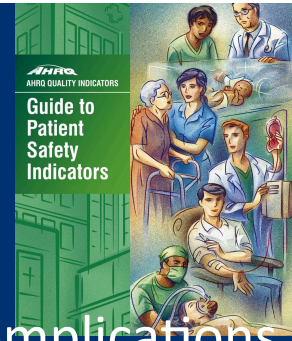


Fig 1 Most common causes of death in the United States, 2013[2]

Makary, MA. Etal. *BMJ* 353 (2016): i2139.

AHRQ PSI's: potentially preventable patient safety incidents



- PSI 02 Death Rate in Low-Mortality Diagnosis- Related Groups (DRGs)
- PSI 03 Pressure Ulcer Rate*
- PSI 04 Death Rate Among Surgical Inpatients with Serious Treatable Complications
- PSI 05 Retained Surgical Item or Unretrieved Device Fragment Count
- PSI 06 Iatrogenic Pneumothorax Rate*
- PSI 07 Central Venous Catheter-related Bloodstream Infection Rate
- PSI 08 Postoperative Hip Fracture Rate*
- PSI 09 Perioperative Hemorrhage or Hematoma Rate*
- PSI 10 Postoperative Physiologic and Metabolic Derangement Rate*
- PSI 11 Postoperative Respiratory Failure Rate*
- PSI 12 Perioperative Pulmonary Embolism or Deep Vein Thrombosis Rate*
- PSI 13 Postoperative Sepsis Rate*
- PSI 14 Postoperative Wound Dehiscence Rate*
- PSI 15 Accidental Puncture or Laceration Rate*
- PSI 16 Transfusion Reaction Count
- PSI 17 Birth Trauma Rate – Injury to Neonate
- PSI 18/19 Obstetric Trauma Rate – vaginal delivery with/wo instrument

* PSI90 component

AHRQ Quality Indicators™

March 2015, 2012 data

PATIENT SAFETY INDICATORS™ v5.0
BENCHMARK DATA TABLES

Indicator	Description	Numerator	Denominator	Observed Rate per 1000
PSI #2	Death Rate on Low-Mortaility DRG's	1,822	5,636,509	0.32
PSI #4	Death Rate among Surgical Inpatients with Serious Treatable Conditions (Cardiac arrest, PE, pneumonia, Sepsis, GI bleed; aka " FAILURE TO RESCUE")	22,014	185,587	118.62
		23,836	28,703 prescript opioid deaths (2014)	

PSI #4 In-hospital Cardiac Arrest

Incidence of cardiac arrest: 1/ 1000 hospital bed days (190,000 in 2012)

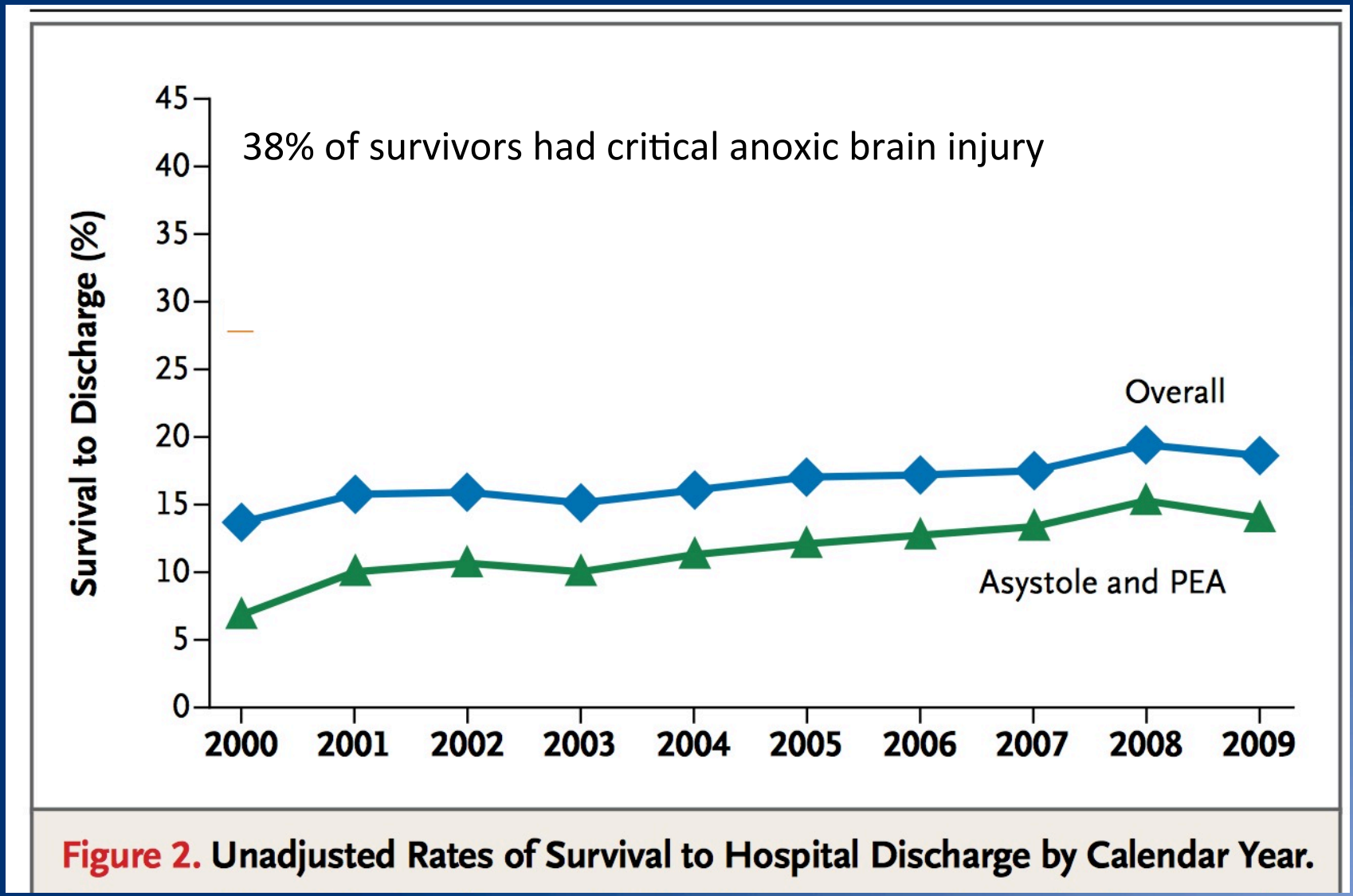


Figure 2. Unadjusted Rates of Survival to Hospital Discharge by Calendar Year.

Girotra, Saket, et al. "Trends in survival after in-hospital cardiac arrest." *New England Journal of Medicine* 367.20 (2012): 1912-1920.

Association of Opioids and Sedatives with Increased Risk of In-Hospital Cardiopulmonary Arrest.

Overdyk FJ, Dowling O, Marino J, et. al.

PLOS ONE 11.2 (2016): e0150214.

Opioids/Sedative Use 2007-1012	Cardiac Arrest (n=96,554)	No Cardiac Arrest (n=12,180,137)	Odds Ratio*	95% CI
Both Opioid and Sedative	41.0 %	21.8%	3.47	(3.40, 3.54)
Opioid only	28.0%	31.4%	1.81	(1.77, 1.85)
Sedative only	13.8%	14.3%	1.82	(1.78, 1.87)
Neither Opioid Nor Sedative	17.2%	32.6%	Ref.	

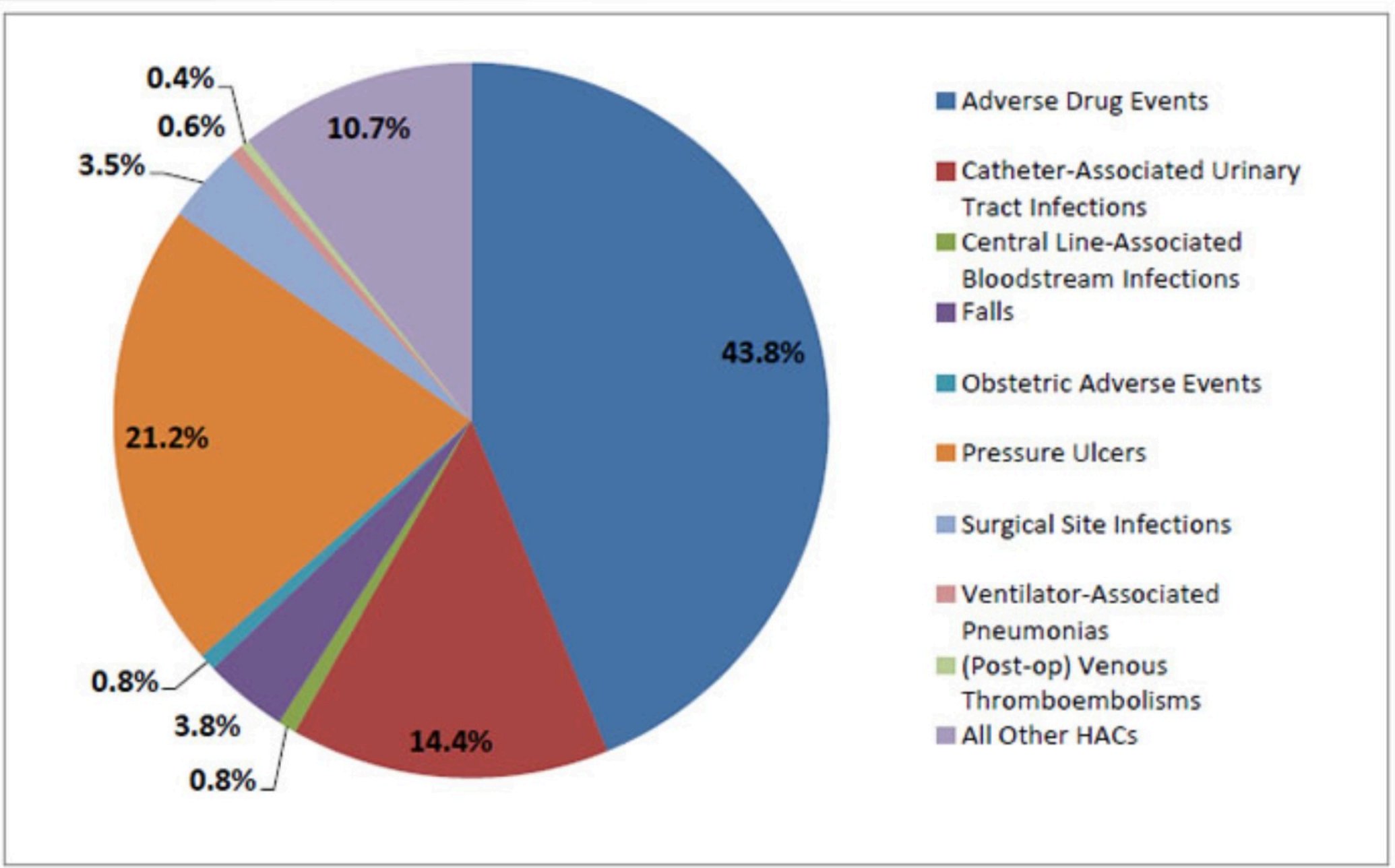
"Low Acuity" Patients	Cardiac Arrest
General Care Floor	21,564

"The names of the patients whose lives we save can never be known. Our contribution will be what did not happen to them....."

Donald M. Berwick, MD, MPP, Institute for Healthcare Improvement, Dec 2004

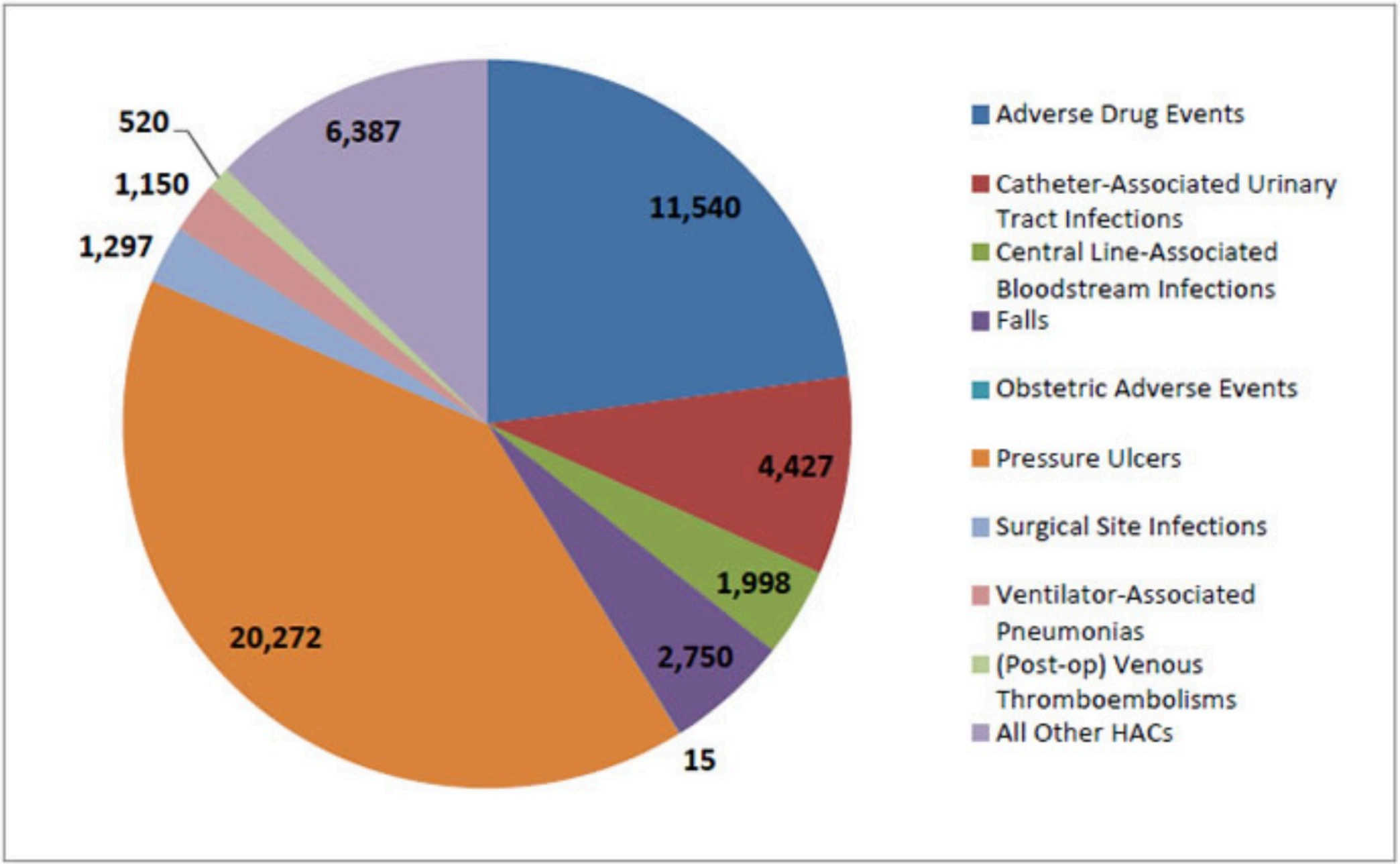
Action:
Deploy Rapid Response Teams (RRT) at the first sign of patient decline

Exhibit 4. Change in HACs, 2011-2013 (Total = 1,317,800)



AHRQ: Interim Update on 2013 Annual Hospital-Acquired Condition Rate and Estimates of Cost Savings and Deaths Averted From 2010 to 2013

Exhibit 6. Estimated Deaths Averted, by Hospital-Acquired Condition (HAC), 2011-2013



AHRQ: Interim Update on 2013 Annual Hospital-Acquired Condition Rate and Estimates of Cost Savings and Deaths Averted From 2010 to 2013

Incidence, Location and Reasons for Preventable in-hospital Cardiac Arrest in a District General Hospital

Hodgetts T, Kenward G, Vlackonikolis I, et. al.

Resuscitation **54: (2002) 115-123**

- 78% of general care ward cardiac arrests (139) were deemed ‘avoidable’.
- The odds of a potentially ‘avoidable’ cardiac arrest was 5.1 times greater for the general care ward than a monitored setting.
- Patients arresting at night and on weekends: 15% chance of survival until discharge and 89% chance of an hypoxic brain injury. (Peberdy, Mary Ann, et al. "Survival from in-hospital cardiac arrest during nights and weekends." *JAMA* 299.7 (2008): 785-792.

Identifying the hospitalised patient in crisis"—A consensus Conference on the Afferent limb of Rapid Response Systems

DeVita M, Smith GB, Adam SK et.al.

Resuscitation *81 (2010) 375–382*

- vital sign aberrations predict risk
- monitoring patients more effectively may improve outcome, although *some risk is random*
- There was agreement that, if practical and affordable, all patients should be monitored continuously.
- concern that current technology is clinically inadequate due to a potential for high false positive or false negative rates
- the workload implications of monitoring on the clinical workforce have not been explored

How do we monitor continuously on a 'low' acuity ward?

- Clinical Acceptability
  - Ergonomics
    - Unencumbering
  - Nursing workflow
    - Initiation monitoring
    - Charting
    - Actionable interventions
  - Alarm Fatigue
    - Alarm threshold settings
    - Notification

Non invasive monitoring

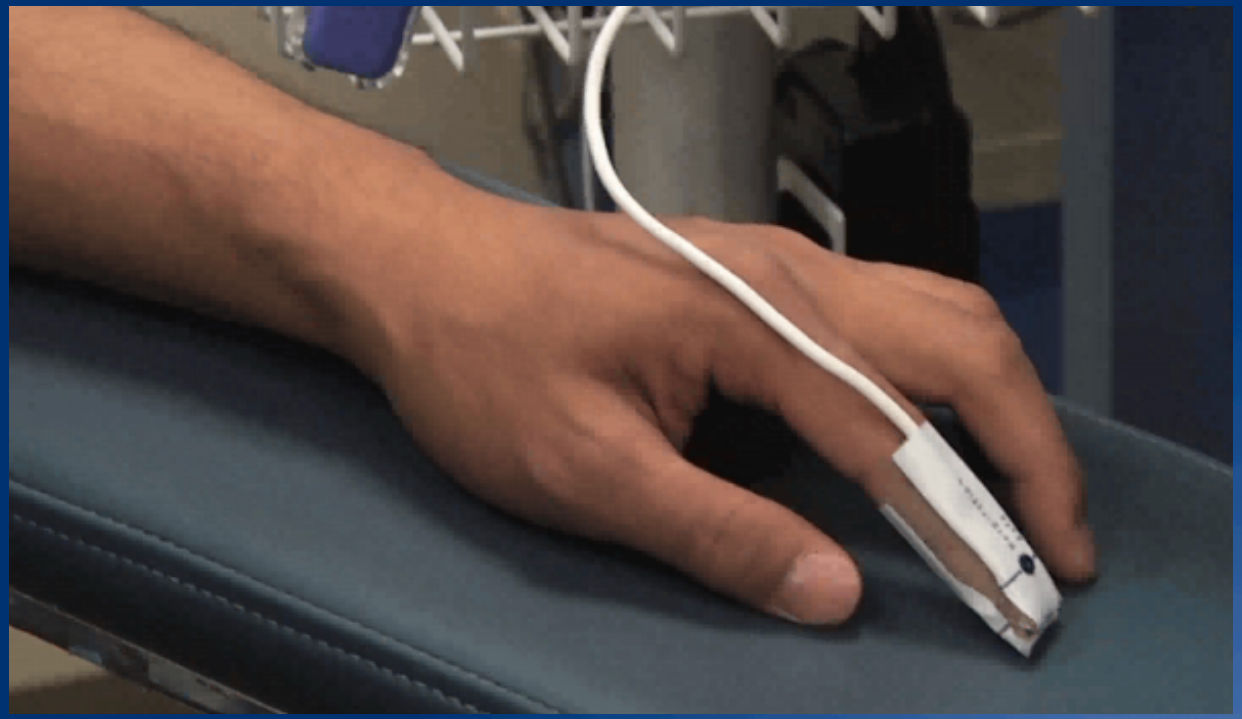
Technologies

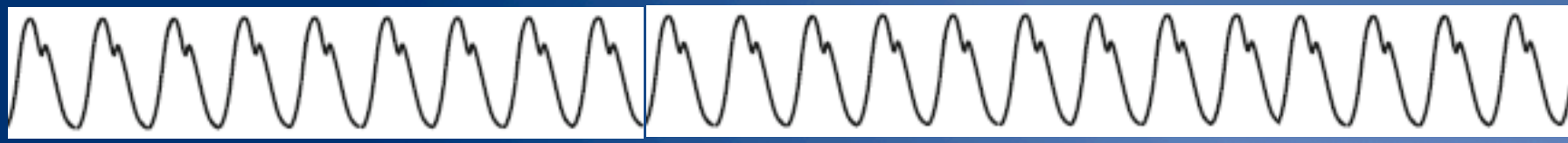
- Photoplethysmography (PPG)
- Impedance plethysmography
- IR detectors (capnography)
- Nasal pressure transducers
- Thermistors
- Bioacoustics
- Piezoelectric
- Severinghaus electrode
- Laser
- Processed EEG

Vital Signs

- Oxygenation: SpO_2, RR
- Chest excursion
- Ventilation: $P_{ET}CO_2$, $P_{tc}CO_2$, V_T, V_E , RR
- Blood pressure: SBP, DBP, MBP
- Temperature
- Level of consciousness

Photoplethsymography (SpO_2, RR, HR)





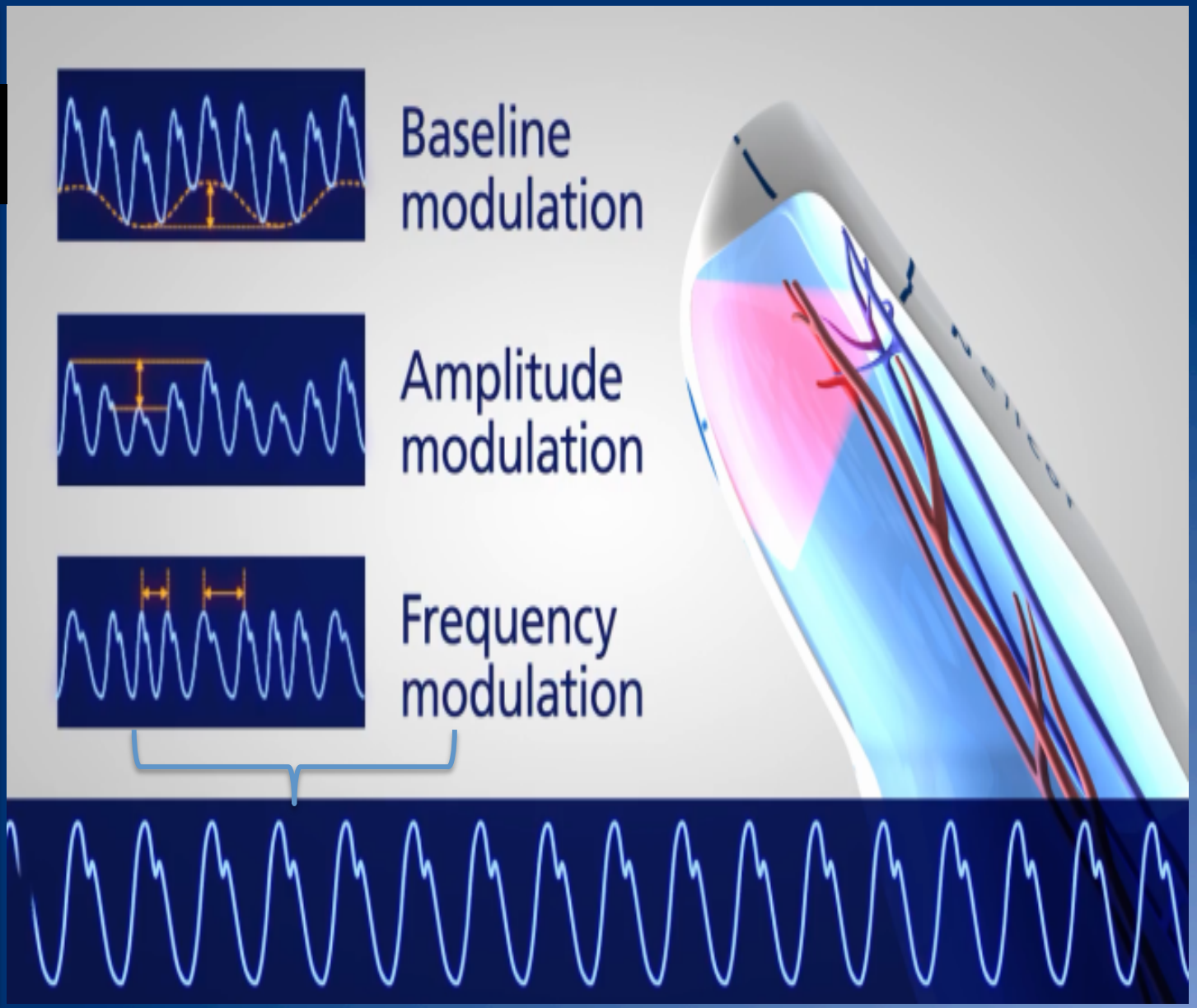
A **plethysmograph** is an instrument that measures and plots changes in **volume** within a structure i.e., vessel, limb, organ.

…intrathoracic PΔ → hemodynamic Δ → volume Δ….

Δ Venous Return

Δ Stroke Volume

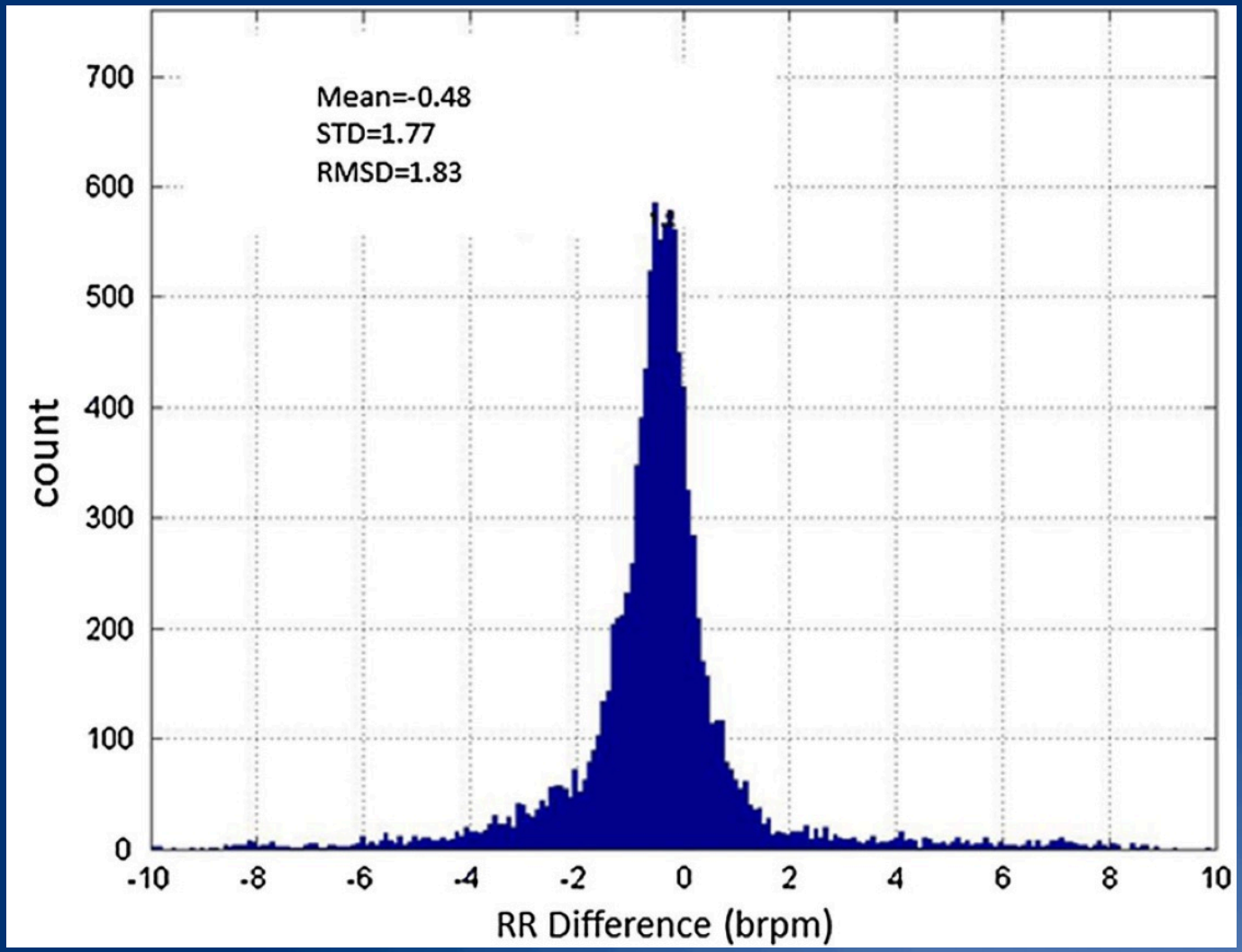
Δ Heart Rate



Courtesy of Covidien

Olsen CO, etal. Diminished stroke volume during inspiration: a reverse thoracic pump. Circulation 72, No. 3, 668-679, 1985.

*Provided by Covidien



Distribution of Differences Between RR_{etCO2} and Rr_{oxi}

- Range of respiration rates observed was 4.7 to 32.0 breaths per minute.

Addison PS, Watson JN, Mestek ML, Ochs JP, Uribe AA, Bergese SD. J Clin Monit Comput. May 6, 2014.

Xhale Assurance: with permission

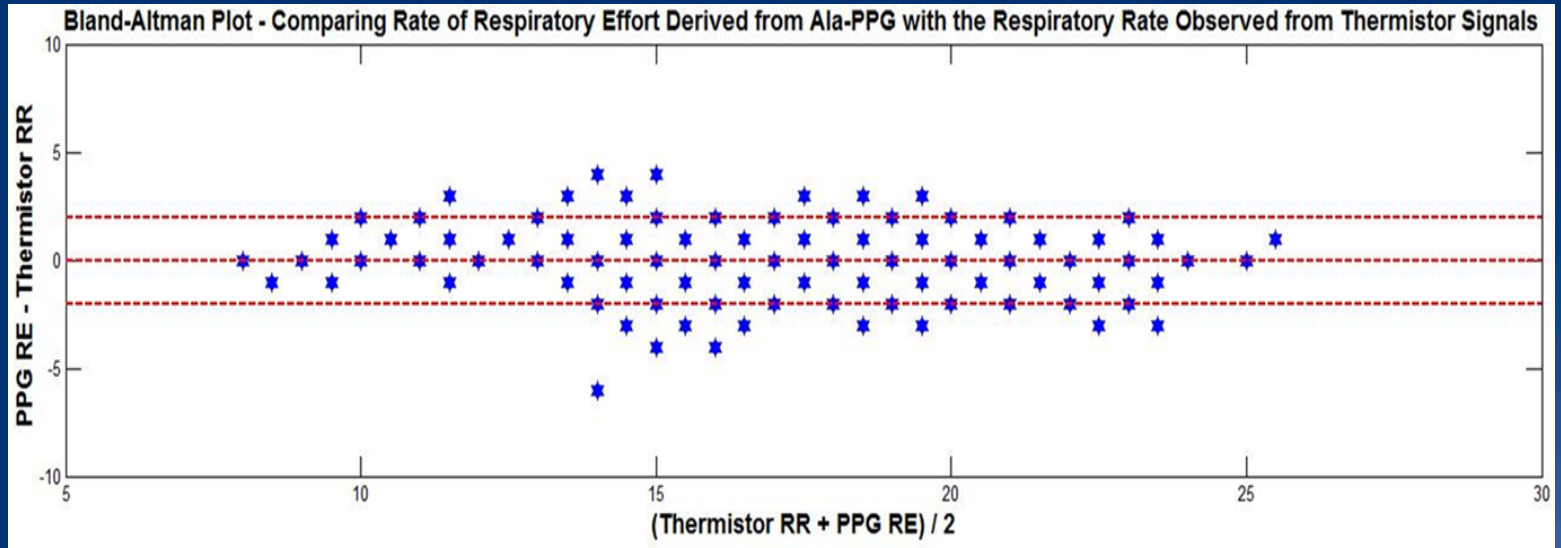
Single Point of Contact (SPOC) Monitoring - multiple sensors

- Photoplethysmography (PPG)
  - Pulse oximetry
    - Heart rate
    - Oxygen saturation
  - Respiratory effort
- Thermistor/NAP/NAF – airflow – RR, apnea

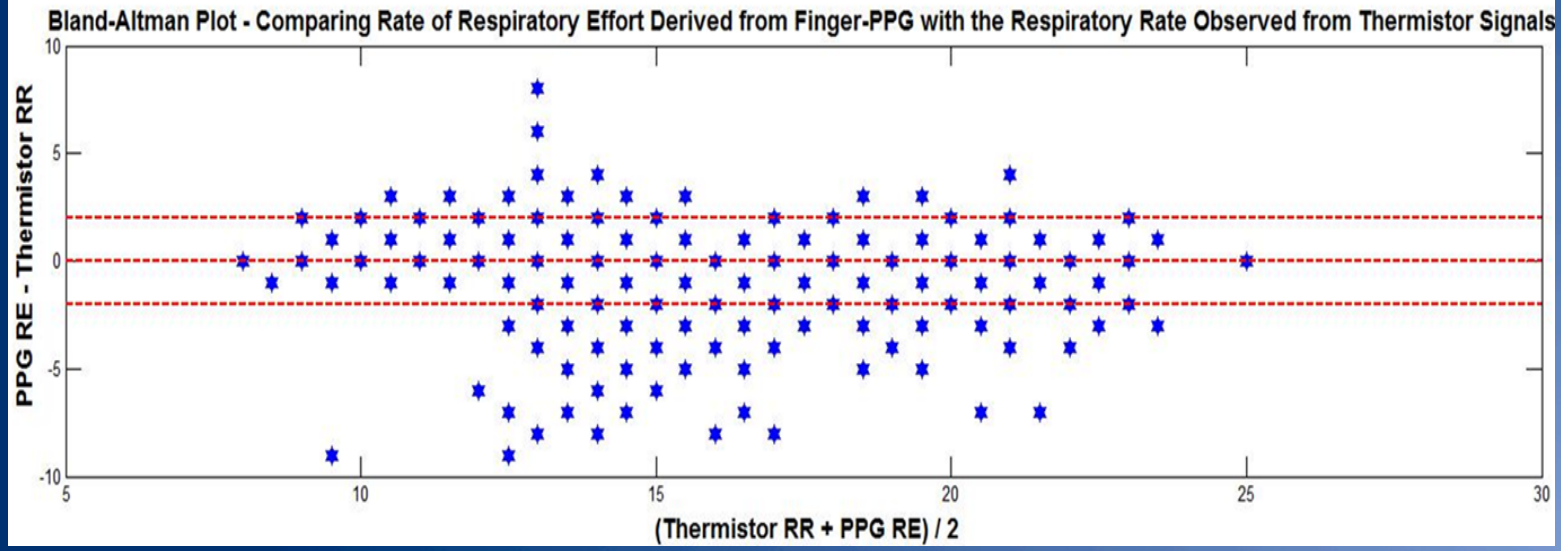
Xhale Assurance: with permission

30 subjects – spontaneous breathing

Nasal Ala PPG



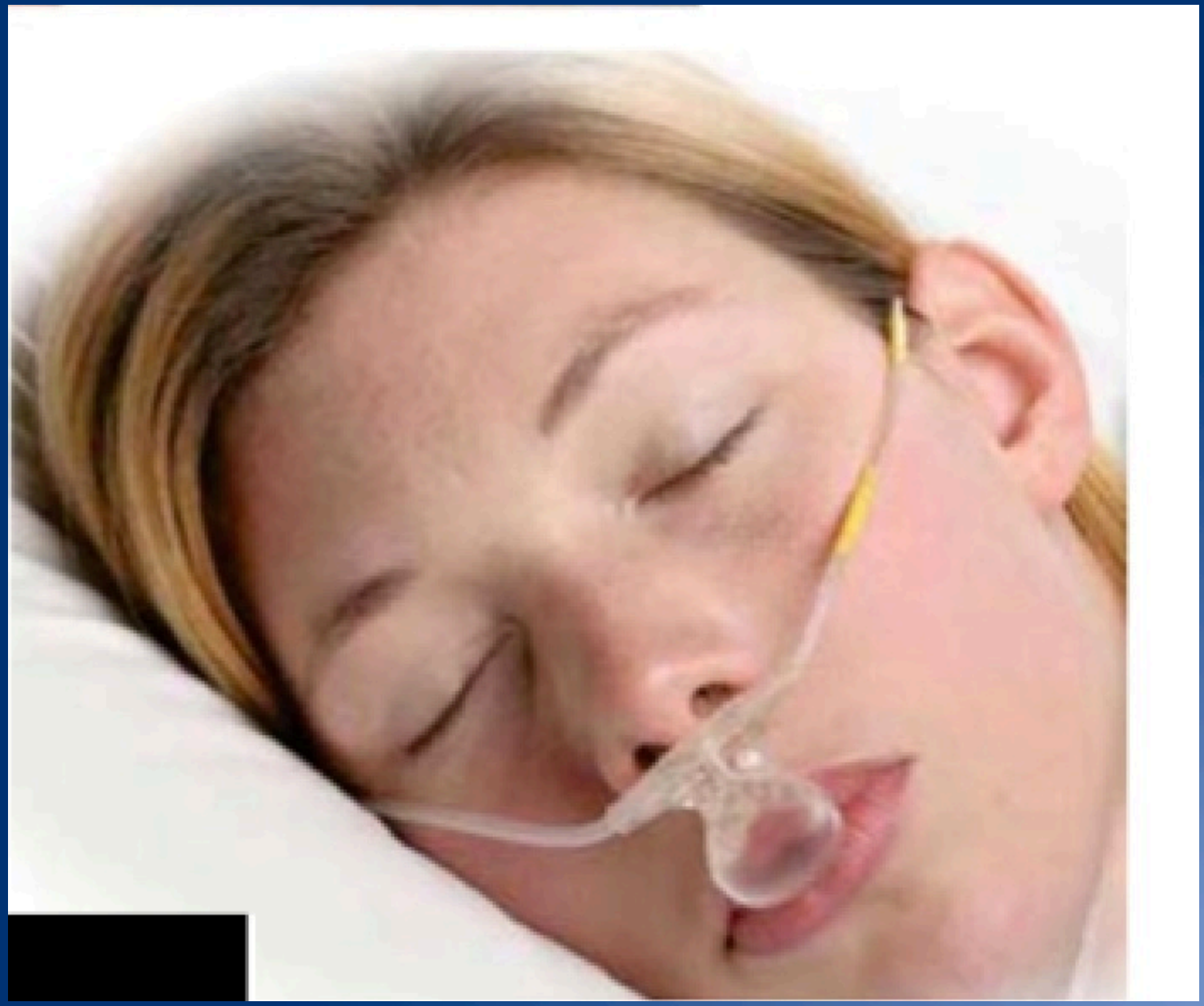
Finger PPG



Airflow monitors (RR and Vt)

- ETCO2 (Capnography)
- Humidity
- Temperature (thermistors)
- Pressure transduced airflow – (PTAF)

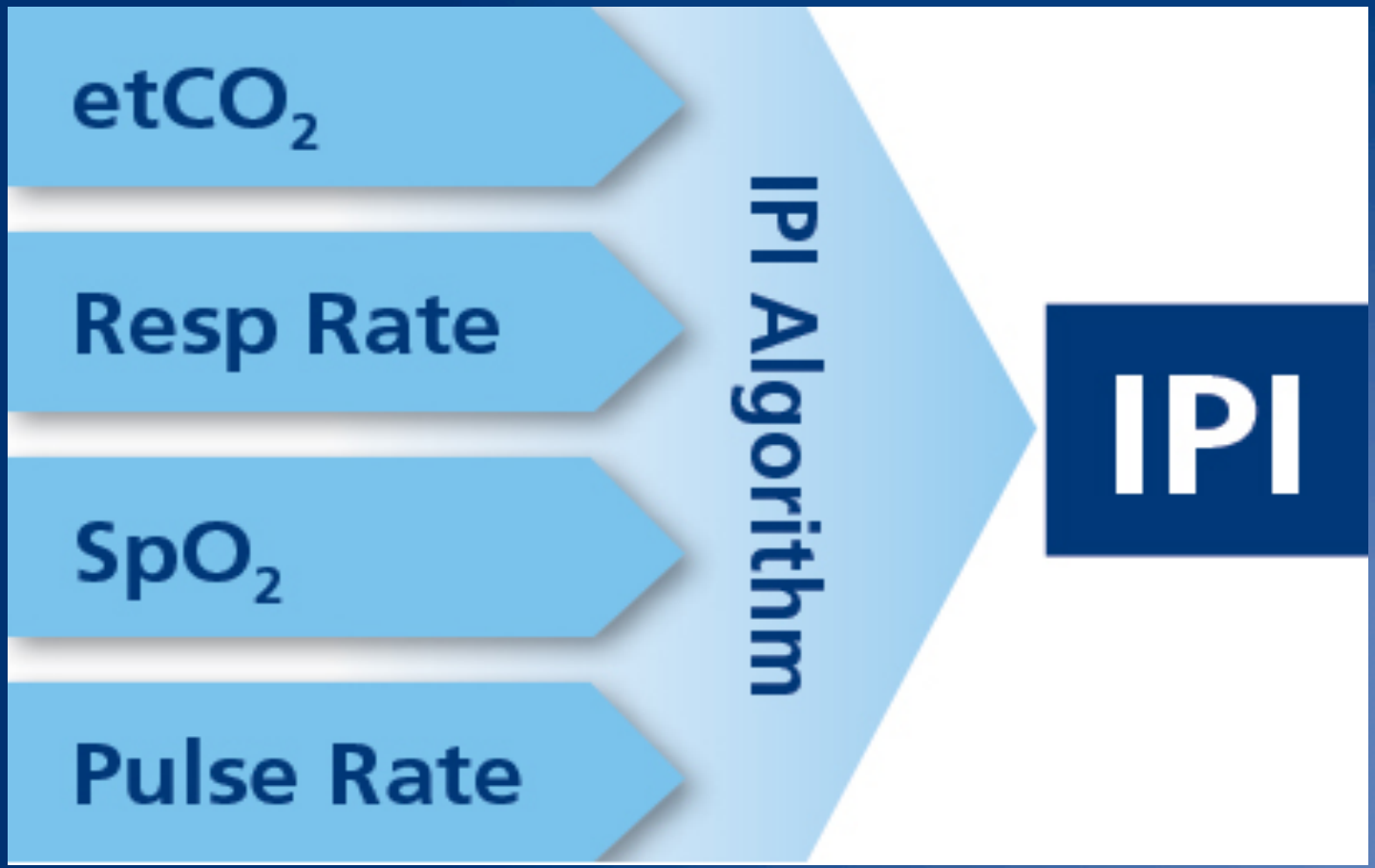
Capnography (RR, $ET_{CO2,}$ patterns)



Covidien Medtronic: with permission

Integrated Pulmonary Index™ (IPI)

Merges 4 parameters- $etCO_2$, RR, HR, SpO_2 into one 'respiratory status' index



*Provided by Covidien

Integrated Pulmonary Index Value:
10 is good, 1 is not

IPI	Patient Status
10	Normal
8-9	With
7	Clos
5-6	Req
3-4	Req
1-2	Req

The value of Integrated Pulmonary Index (IPI) monitoring during endoscopies in children

Garah, Jamal, et al.

Journal of clinical monitoring and computing 29.6 (2015): 773-778.

- IPI alerted all apnea episodes (58 events, IPI = 1) and hypoxia (26 events, IPI ≤ 3) episodes
- Pulse oximetry captured only the hypoxia episodes (IPI sensitivity = 1, specificity 0.98, positive predictive value 0.95).

Bioacoustics: RR

Masimo: with permission

Assessment of continuous acoustic respiratory rate monitoring as an addition to a pulse oximetry-based patient surveillance system

McGrath, Susan P., Joshua Pyke, and Andreas H. Taenzer.
Journal of clinical monitoring and computing (2016): 1-9.

- The vast majority (82 %) of low oxygen saturation states coincided with normal respiration rates of 12–20 breaths/min.
- ….adding continuous respiratory rate monitoring to a pulse oximetry-based surveillance system may not significantly improve patient deterioration detection.

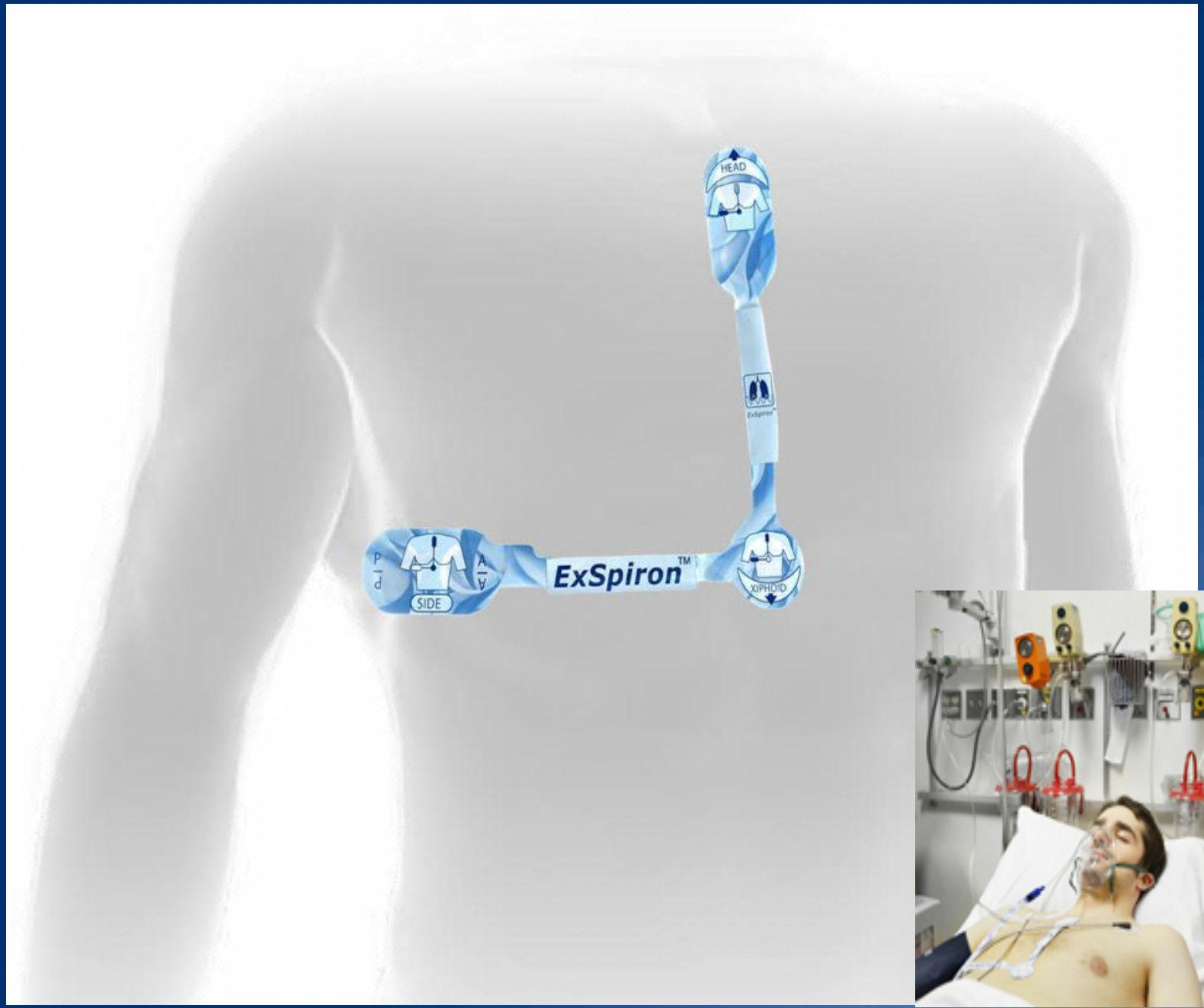
Postoperative Hypoxemia Is Common and Persistent: A Prospective Blinded Observational Study

Zhuo Sun, MD,* Daniel I. Sessler, MD,*† Jarrod E. Dalton, PhD, et.al.

Anesth Analg 2015;121:709–15

- 37% of patients had an SpO2 <90% for an hour or more.
- The nurses were unaware of 90% of hypoxemic episodes (SpO2 <90% for at least one hour).

Impedance plethysmography: RR & Vt

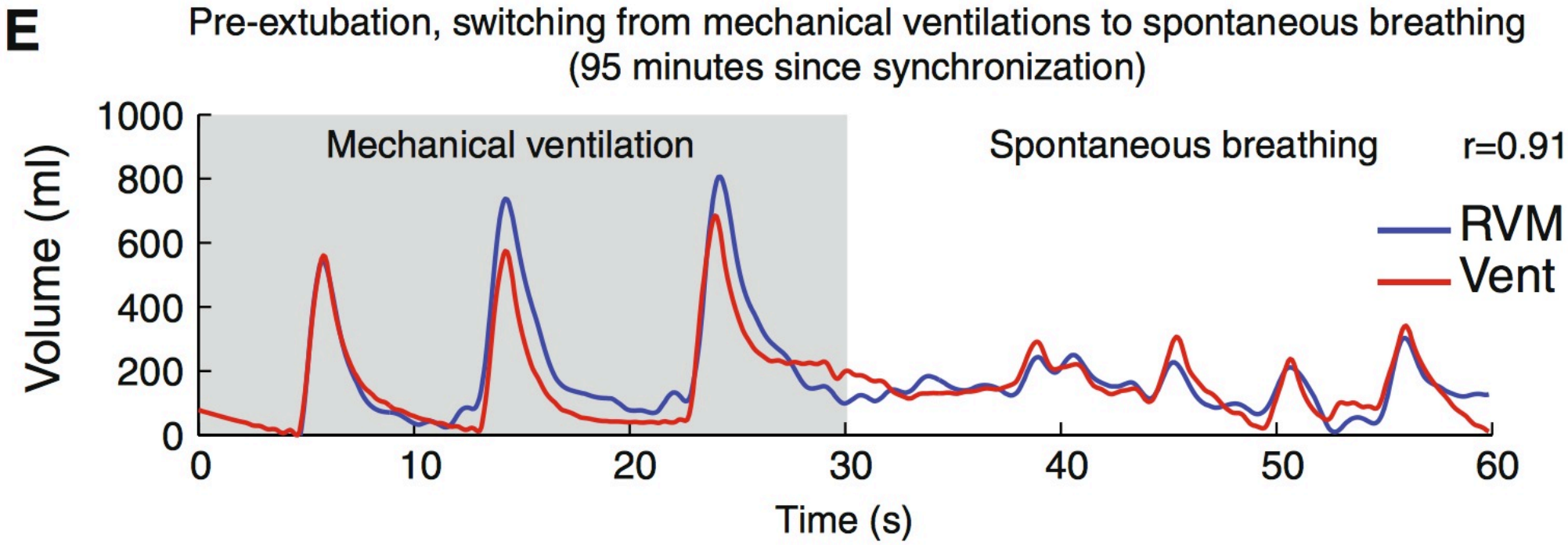


Respiratory Motion; with permission

The evaluation of a non-invasive respiratory volume monitor in surgical patients undergoing elective surgery with general anesthesia.

Christopher J. Voscopoulos • C. Marshall MacNabb • Jordan Brayanov • Lizeng Qin • Jenny Freeman • Gary John Mullen • Diane Ladd • Edward George

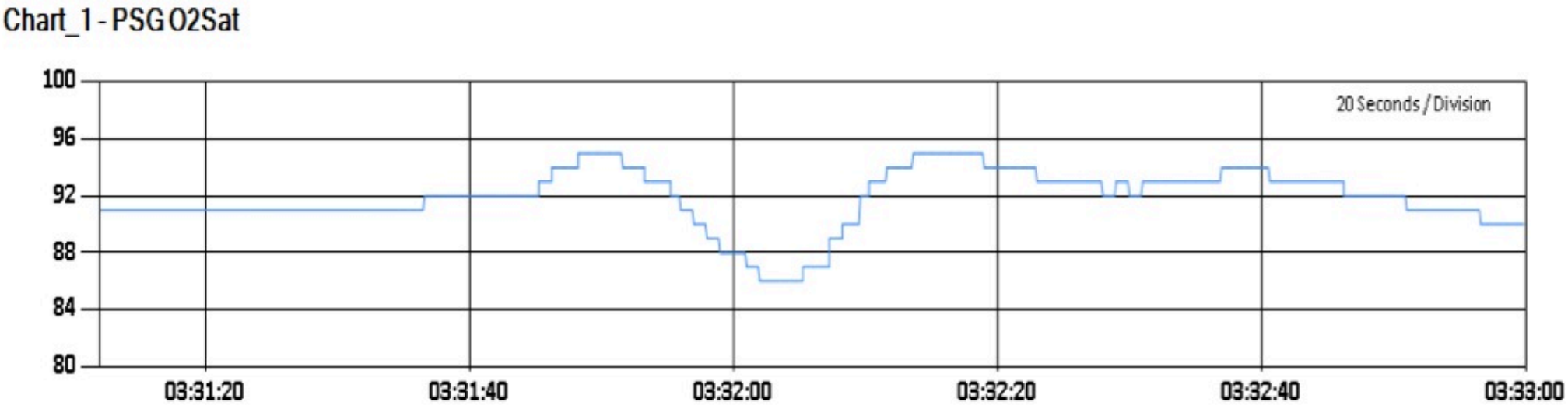
Journal of clinical monitoring and computing. April 2015, Volume 29,



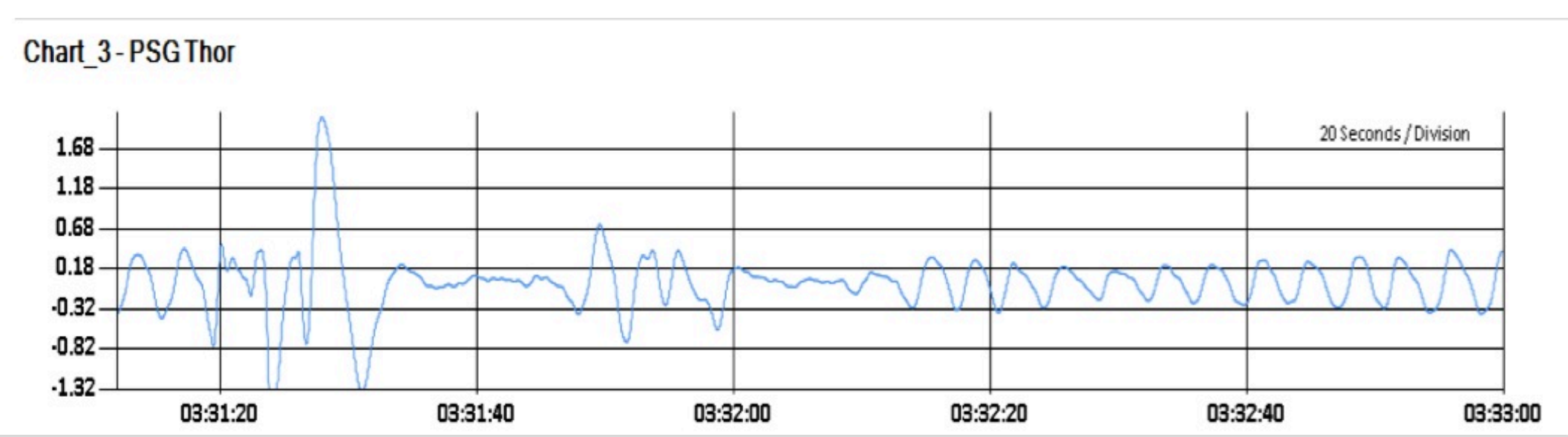
MultiSense™

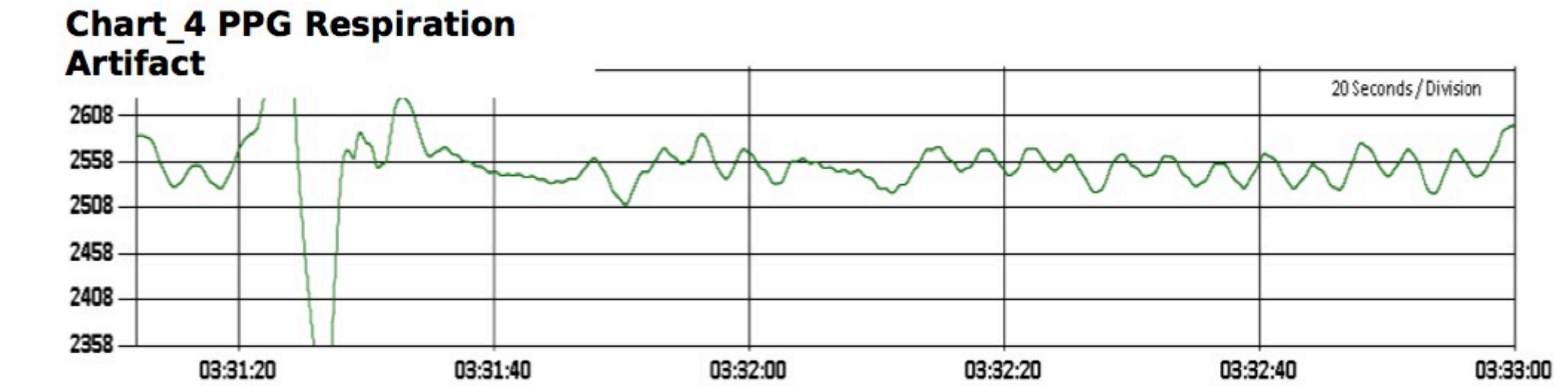
- **Heart rate & variability**
- **Oxygen saturation**
- **Respiratory rate & depth**

Rhythm Diagnostic Systems; with permission

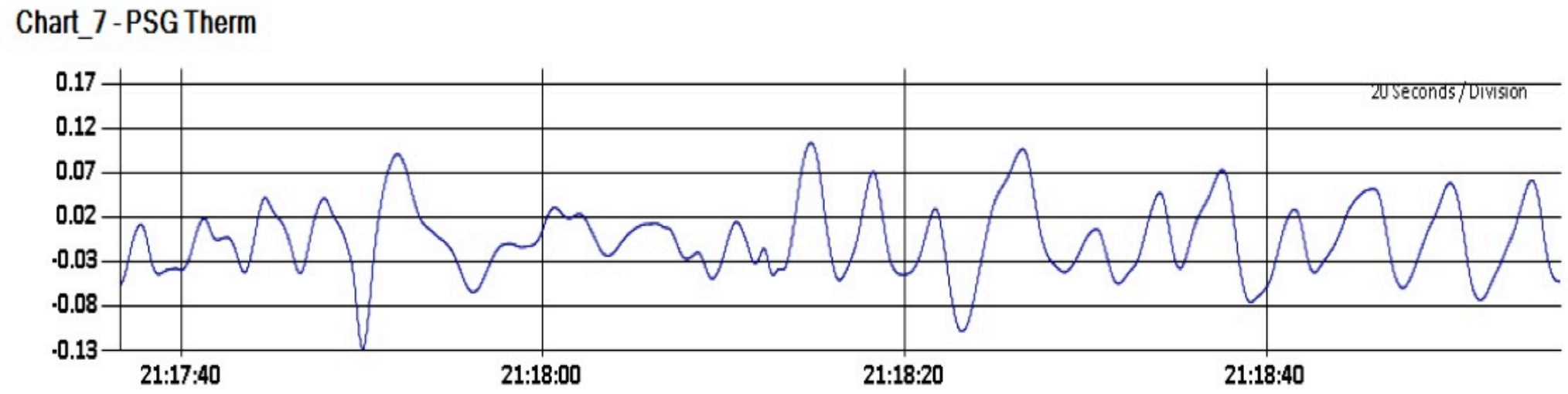


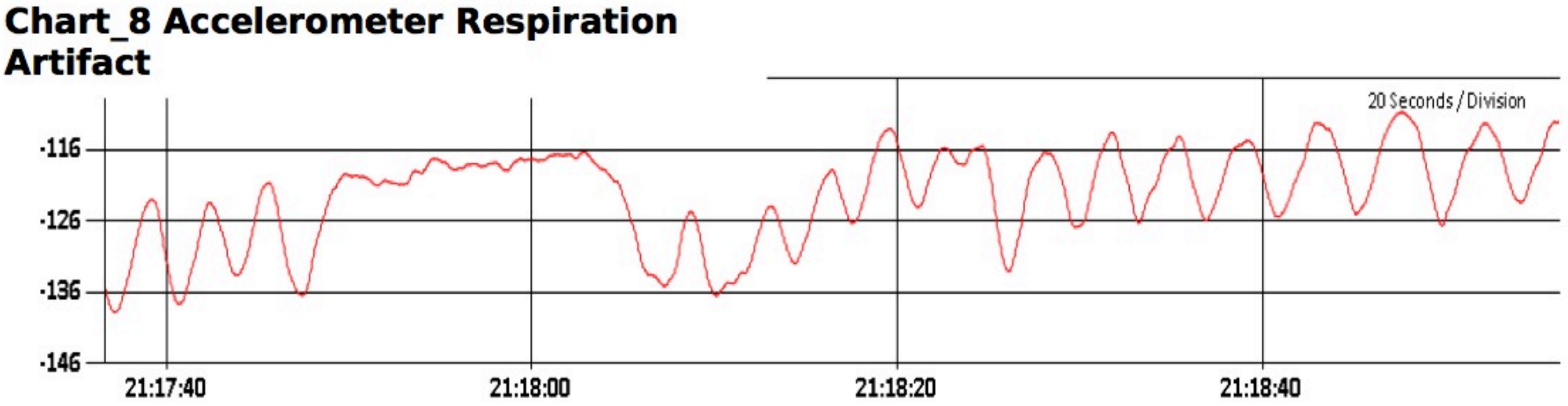
Rhythm Diagnostic Systems; with permission





Rhythm Diagnostic Systems; with permission





Rhythm Diagnostic Systems; with permission

Piezoelectric sensor: RR, HR

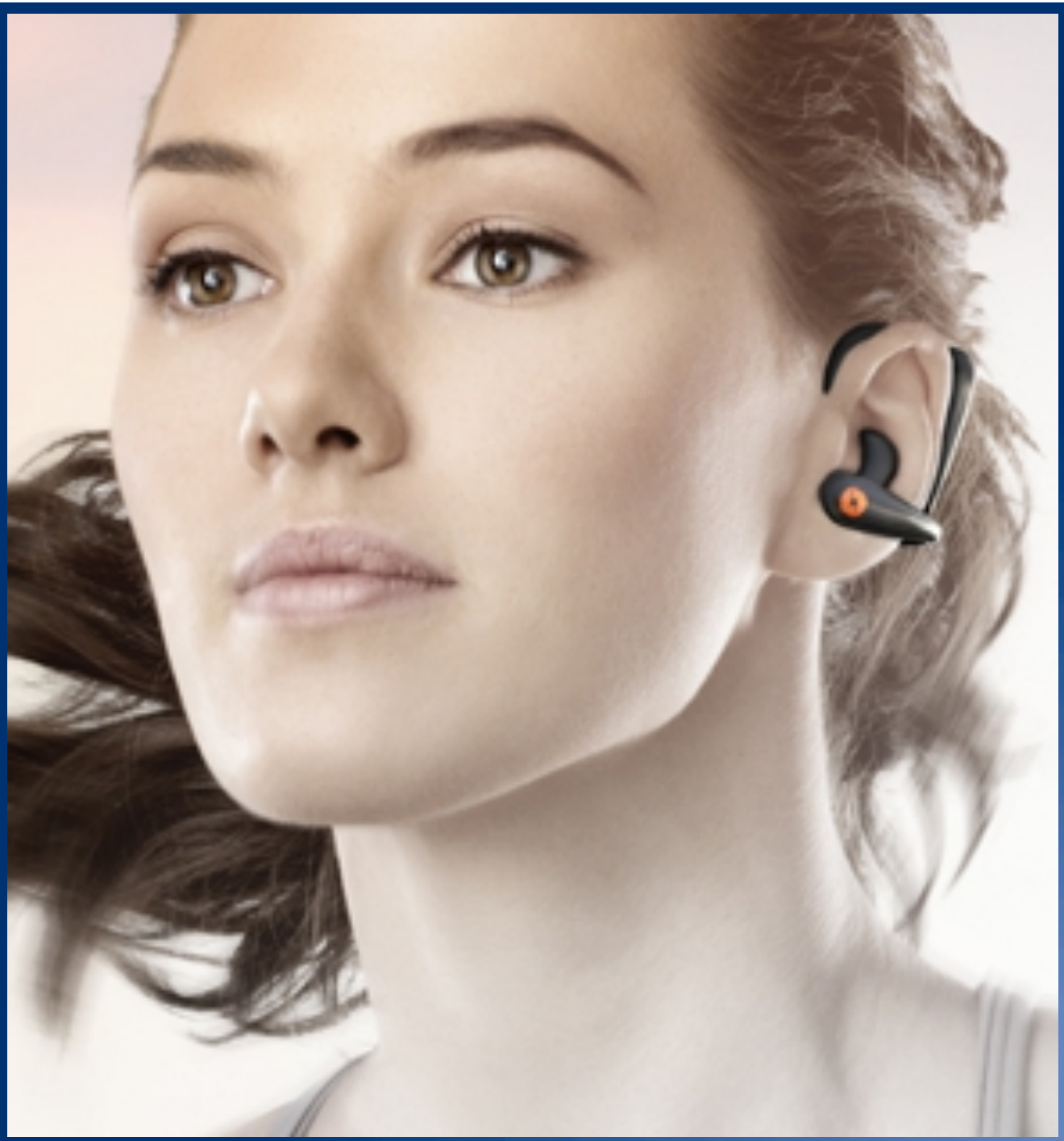
Early Sense™: with permission

Impedance Pleth, PPG: Continuous RR, SpO2, HR and NIBP

Sotera: with permission

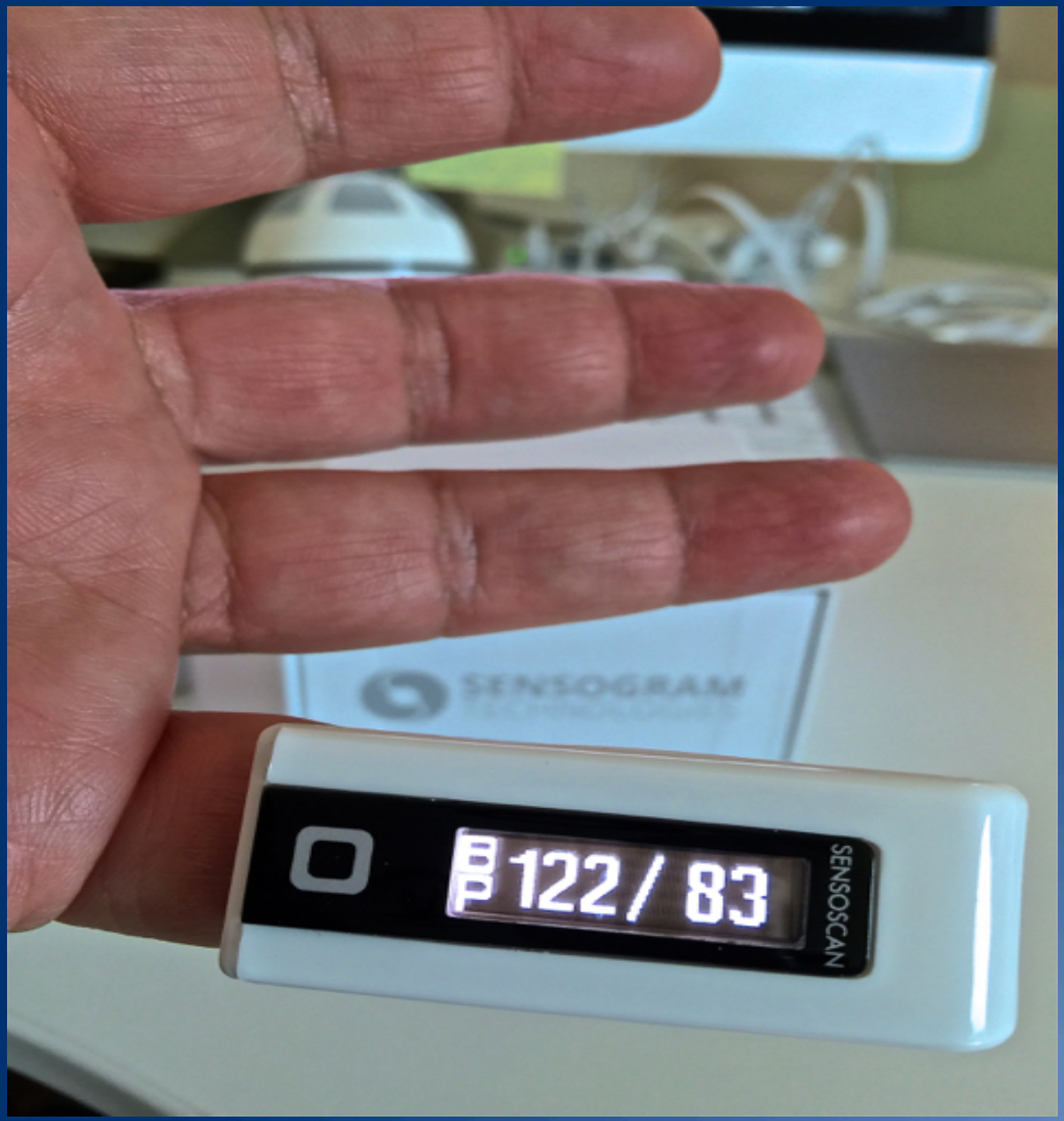

12:45


JAWBONE



Not a medical device!

Sensogram Tech: with permission



Sensogram Tech: with permission

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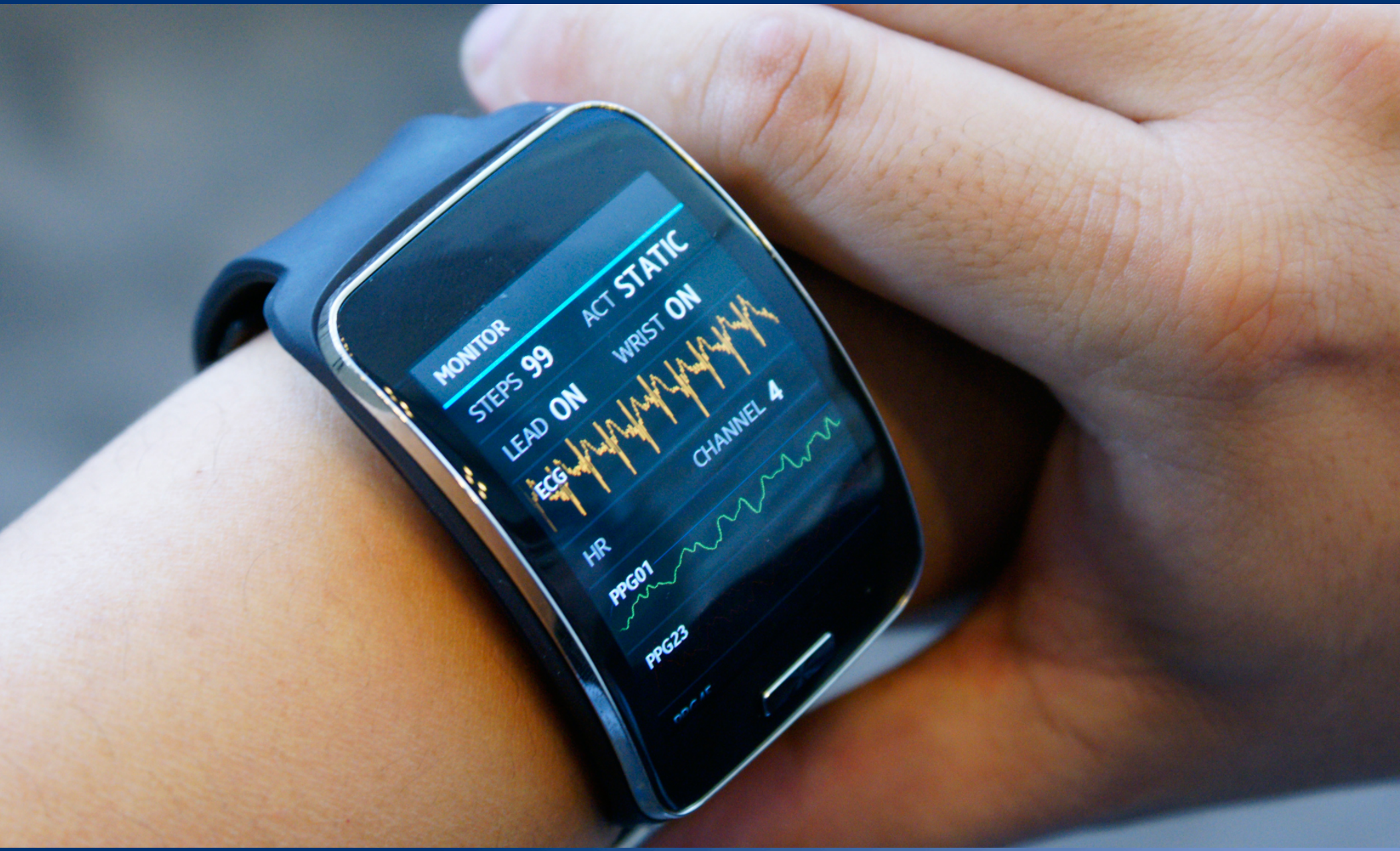


Elfi-Tech; with permission

Barriers to adoption of continuous vital sign monitoring

- "Lacking evidence of improved outcomes"
- "Disruptive to nursing workflow"
- "Too many false alarms"
- "Too expensive"

Impact of Pulse Oximetry Surveillance on Rescue Events and Intensive Care Unit Transfers. A Before-and-After Concurrence Study

Taenzer AH, Pyke JB, McGrath SP, Blike GT.

Anesthesiology 2010, 112: 282-7

Methods: Before/after implementation in a 36-bed orthopedic unit.

Results:

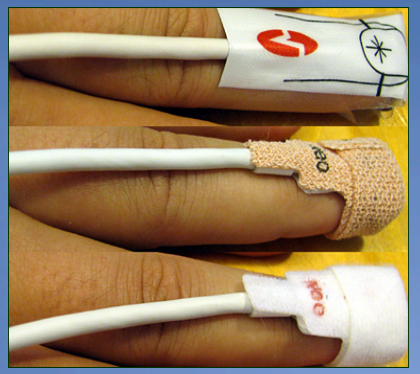
- 50% reduction in transfers to higher levels of care
- 60% reduction in rescue events
- 0 Dead in Beds

Alarms:

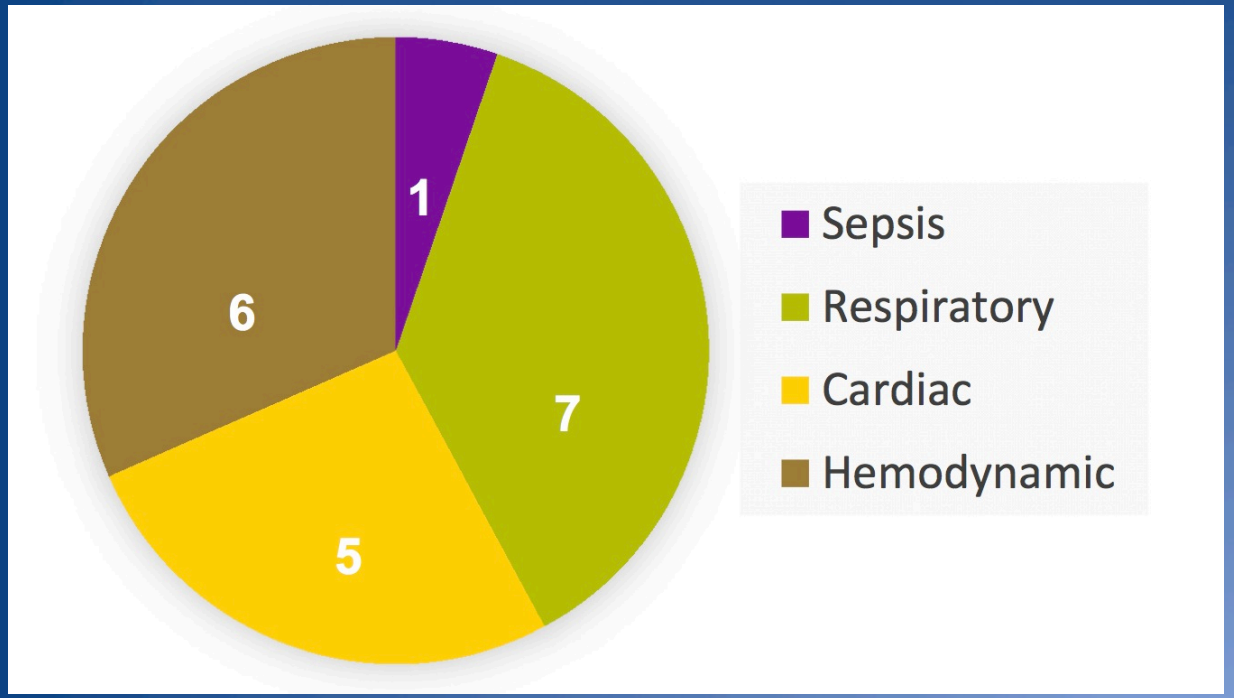
- alarm rates 2-4 per patient per 12 hour shift.
- 85% of all alarm conditions are resolved w/i 30 sec

Financial:

- $85 per patient deployment year; $22 per patient



- A total of 1,500 patients were monitored for 60,000 hours
- At least 19 events that would have likely resulted in failure to rescue: PE's, sepsis, MI's



Wake Forest Baptist Medical Center: Presented at AAMI

Parameter	Alarms/ Patient/ Day
SpO2	1.1
Cardiac Rate	0.8
Resp Rate	0.4
Continuous BP	0.4
TOTAL	**2.7**

Wake Forest Baptist Medical Center: Presented at AAMI

Continuous Monitoring in an Inpatient Medical-Surgical Unit: A Controlled Clinical Trial

Harvey Brown, MD Jamie Terrence, RN,a Patricia Vasquez, RN, BSN,
David W. Bates, MD, MSc, Eyal Zimlichman, MD, MS

The American Journal of Medicine (2014) 127, 226-232

- Rate of code blue events decreased from 6.3 to 0.9 and 2.1, respectively, per 1000 patients (P=.02)
- Average length of stay (LOS) decreased from 4.0 to 3.6 days; P <.05).

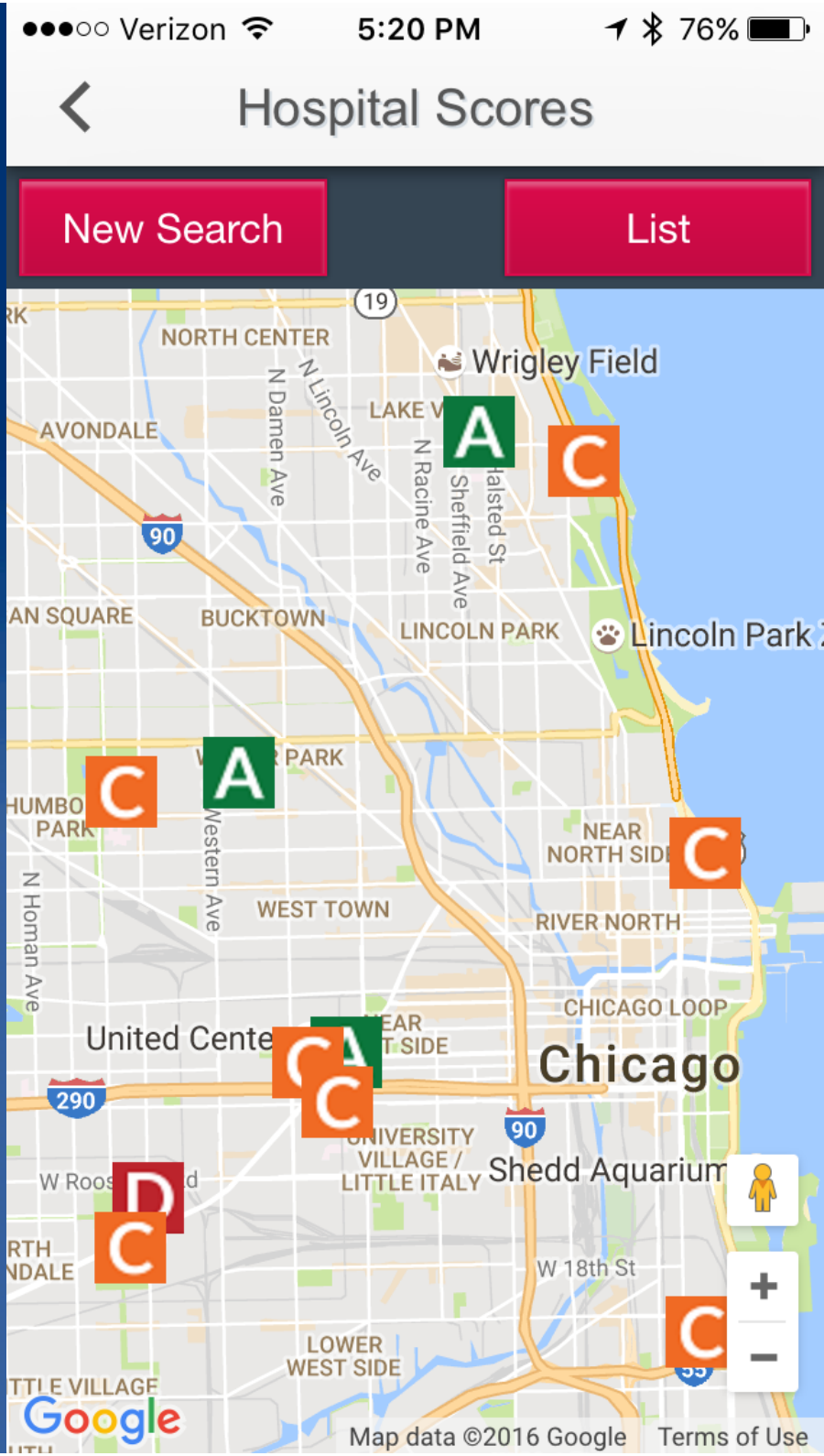
Alarm fatigue

Average number of alerts per 12 hours shifts (for all nurses)	**12**
Average number of alerts per 12 hours shift per nurse (assuming 6 nurses on shift)	**2**
Estimated false alerts per nurse per shift	**0.60**

HOSPITAL SAFETY SCORE®

"…selecting the right hospital can reduce your risk of avoidable death by 50%"

Grade	Safety Score Criteria *(at or above cut-point)*		Count of Hospitals	Percentage of Hospitals
A	≥ 3.164	0.6 SDs Above Mean	798	31%
B	≥ 2.972	0.0 SDs Above Mean	639	25%
C	≥ 2.493	1.5 SDs Below Mean	957	37%
D	≥2.014	3.0 SDs Below Mean	162	6%
F	<2.014	More than 3.0 SDs Below Mean	15	1%
Totals			2571	



Thank you!