Current And Future Objective Monitors Outside The ICU

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RESPIRATORY CARE
Disclosures

• Philips Respironics
• Pari
• Merck
• Bayer
• McGraw-Hill
• Jones and Bartlett
• UpToDate
• Pulmonary Disease Board, ABIM
Monitoring

• Monitoring is the continuous, or nearly continuous, evaluation of the physiologic function of a patient in real time to guide diagnosis and management decisions - including when to make therapeutic interventions and assessment of those interventions.

_Hess, Respir Care 1990;35:482_
Respiratory Monitoring

• Gas exchange
  – Pulse oximetry
  – Capnography
• Respiratory rate
• When and who to monitor?
Hess, Respiratory Care: Principles and Practice
Pulse Oximetry

- **accuracy (± 4%)**
- differences between probes and devices
- penumbra effect
- dyshemoglobinemias
- endogenous and exogenous dyes and pigments
- skin pigmentation
- perfusion
- anemia
- motion
- high intensity ambient light
- abnormal pulses

Importance of staff education
Hess, Respiratory Care: Principles and Practice
Impact of Pulse Oximetry Surveillance on Rescue Events and Intensive Care Unit Transfers

A Before-and-After Concurrence Study

Andreas H. Taenzer, M.D., F.A.A.P.,* Joshua B. Pyke, B.E.,† Susan P. McGrath, Ph.D.,‡ George T. Blike, M.D.§

Anesthesiology 2010;112:282
False Alarms

• Prospective, observational study of the alarm and paging data from a convenience sample of adults who were consecutively admitted to a 32 bed general care unit following orthopedic surgery over a 3 month period.

• Only a third of pulse oximetry alarm notifications were for clinically relevant oxygen desaturation, but did facilitate timely nursing response and intervention for most patients.

Of monitoring-triggered interruptions to care, only 20% were true and clinically meaningful.

_Gross, Biomedical Instrumentation and Technology Supplement 29–36._
Capnography
Normal Capnogram

PCO₂ vs time

COPD, asthma

End-tidal PCO₂
decreased \( \dot{V}/\dot{Q} \)  
(normal)  
increased \( \dot{V}/\dot{Q} \)

\( P_{ETCO_2} \approx P_{VCO_2} \)
\( P_{ETCO_2} \approx PaCO_2 \)
\( P_{ETCO_2} \approx PI_{CO_2} \)

End-tidal \( PCO_2 \) may be different from \( PaCO_2 \)
Capnography for Sedation Monitoring

**Normal Ventilation**
- normal respiratory rate
- normal tidal volume
- normal alveolar ventilation
- normal dead space fraction
- normal PaCO₂
- normal P(a-et)CO₂

**Result**
ETCO₂ similar to PaCO₂

**Bradypneic Hypoventilation**
- ↓ respiratory rate
- normal tidal volume
- ↓ alveolar ventilation
- normal dead space fraction
- ↑ PaCO₂
- normal P(a-et)CO₂

**Result**
↑ ETCO₂

**Hypopneic Hypoventilation**
- normal respiratory rate
- ↓ tidal volume
- ↓ alveolar ventilation
- ↑ dead space fraction
- ↑ PaCO₂
- ↑ P(a-et)CO₂

**Result**
normal, or ↓ ETCO₂
• Adults who underwent ED propofol sedation randomized to capnography or not.
• Every patient with hypoxia first exhibited capnographic evidence of respiratory depression.

- 63% of patients with capnography dokumented respiratory depression had a decrease in end-tidal PCO₂ greater than 10%.

A randomized controlled trial of capnography during sedation in a pediatric emergency setting

Melissa L. Langhan, MD, MHS a,*, Veronika Shabanova, MPH b, Fang-Yong Li, MPH, MS b, Steven L. Bernstein, MD c, Eugene D. Shapiro, MD a,d

• 154 children receiving procedural sedation were randomized to whether staff could view the capnograph monitor or were blinded to it (controls).
• 45% had at least 1 episode of hypoventilation.
• There were significantly fewer interventions (stimulation, BVM, jaw thrust, etc) in the study group (OR 0.25).
• Interventions were more likely to occur contemporaneously with hypoventilation in the intervention group.

• All episodes of hypoventilation were caused by hypopnea, with end-tidal PCO₂ < 30 mm Hg.

PCA With Oximetry and Capnography
Respiratory rate: the neglected vital sign

Michelle A Cretikos, Rinaldo Bellomo, Ken Hillman, Jack Chen, Simon Finfer and Arthas Flavouris

- Respiratory rate is often not recorded.
- An abnormal respiratory rate is a predictor of potentially serious clinical events.
- Clinicians need to be more aware of the importance of an abnormal respiratory rate.
- Hospital systems that encourage appropriate responses to elevated respiratory rate can be rapidly implemented.

_MJA 2008; 188: 657–659_
Respiratory Rate As An Indicator Of Serious Illness

• Respiratory rate >27 was an important predictor of cardiac arrest in hospital wards. J Gen Intern Med 1993;8:354

• Respiratory rate is likely better than HR and SBP to discriminate between stable patients and those at risk. Anaesthesia 2003;58:797-802

• 21% of ward patients with a respiratory rate of 25-29 died in the hospital. Anaesthesia 2005;60:547

• Half of patients with a serious adverse event on the general wards had a respiratory rate >24. Resuscitation 2007;73:62
The routine repeated measurement of the respiratory rate is of clinical value in less than 5% of patients in a hospital, and furthermore physicians themselves rarely show an interest in such measurements. As a result of such indifference, nurses have been increasingly casual in their measurement of respiratory rates, and, in many cases, though a figure is recorded, no actual measurement was made. In one carefully controlled experiment measurements of respiratory rate were carried out in 58 patients within minutes of the routine ward measurements. The ward records showed 57 of these patients as having a rate between 18 and 22 per minute; 40 having a rate of exactly 20. The real range was from 11 to 33 per minute, only five patients showing a rate of 20. If recording the respiratory rate is important, the character of the breathing is of equal importance. Nursing personnel should recognize abnormal breathing patterns and bring these abnormal findings to the attention of the physician. It is suggested that routine recording of respiratory rates be limited to those cases or on those hospital wards where the physician specifically orders such measurements. This not only would improve the accuracy of the measurements and clinical records but also would save millions of hours of personnel time each year.
Respiratory Rate

• Tachypnea: respiratory distress, metabolic acidosis, pain, increased metabolic rate (fever)
• Bradypnea: respiratory center depression (opioid)
<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Regular and comfortable, 12 to 20 breaths per minute</td>
</tr>
<tr>
<td>Air trapping</td>
<td>Increasing difficulty in getting breath out</td>
</tr>
<tr>
<td>Ataxic</td>
<td>Significant disorganization with irregular and varying depths of respiration</td>
</tr>
<tr>
<td>Biot respirations</td>
<td>Irregularly interspersed periods of apnea in a disorganized sequence of breaths</td>
</tr>
<tr>
<td>Bradypnea</td>
<td>Slower than 12 breaths per minute</td>
</tr>
<tr>
<td>Cheyne-Stokes breathing</td>
<td>Varying periods of increasing depth interspersed with apnea</td>
</tr>
<tr>
<td>Hyperpnea</td>
<td>Faster than 20 breaths per minute, deep breathing</td>
</tr>
<tr>
<td>Kussmaul respirations</td>
<td>Rapid, deep, labored breathing</td>
</tr>
<tr>
<td>Sighing</td>
<td>Frequently interspersed deeper breaths</td>
</tr>
<tr>
<td>Tachypnea</td>
<td>Faster than 20 breaths per minute</td>
</tr>
</tbody>
</table>

*Hess, Respiratory Care: Principles and Practice*
Measurement of Respiratory Rate

- Inspection
- Capnography
- Pulse oximetry
- Impedance
- Belts and thermistors
- Optical technology
- Acoustic technology
Hess, Respiratory Care: Principles and Practice
Airflow (nasal thermistor)

Chest excursion (piezoelectric belt)
Optical Methods

• Camera used to detect thoracic movements to determine respiration rate.

Nakajima, Physiol Meas 2001;22:21
Thermal Imaging

Fig. 3. (a) A thermal image with tip of the nose represented by a circle, (b) the eight segments of the selected respiration region.

AL-Khalidi, Pediatric Pulmonology 2011;46:523
Facial color change for heart rate

Optical imaging for respiratory rate

Results
Pulse Oximeter

Tap START to begin - don’t cover camera
FINISHED

60 BPM
Measuring heart rate

SpO2 96%

START
Pulse Ox Pleth Waveform: Pulsus

Hartert, Chest 1999;115:475
Pulse Ox Pleth Waveform: Fluid Responsiveness

Cannesson, Crit Care 2005;9:R562
Pulse Ox Pleth for Respiratory Rate

Addison, J Clin Monit Comput 2015;29:113
Fig. 4 Bland-Altman density plot of the data (lowest density of points to highest density = Dark Blue, Light Blue, Green, Yellow, Red)

Addison, J Clin Monit Comput 2015;29:113
The Accuracy, Precision and Reliability of Measuring Ventilatory Rate and Detecting Ventilatory Pause by Rainbow Acoustic Monitoring and Capnometry

Michael A. E. Ramsay, MD,* Mohammad Usman, PhD,† Elaine Lagow, RN,‡ Minerva Mendoza, RN,§ Emylene Untalan, RN,§ and Edward De Vol, PhD||

Anesth Analg 2013;117:69
33 PACU patients exhibiting a wide range of ventilation rates.
- The reliability of both devices was high.
- The acoustic monitor was about 3% more precise than capnography.
- Did not address whether the better accuracy/precision of RAM was clinically important.
Evaluation of a Novel Noninvasive Respiration Monitor Providing Continuous Measurement of Minute Ventilation in Ambulatory Subjects in a Variety of Clinical Scenarios

Anesth Analg 2013;117:91

Christopher Voscopoulos, MD,* Jordan Brayanov, PhD,† Diane Ladd, DNP,‡ Michael Lalli, BSE,† Alexander Panasyuk, PhD,† and Jenny Freeman, MD†

- RVM (ExSpiron, Respiratory Motion, Inc., Waltham, MA).
- 1 electrode pad comprising 3 electrodes is placed along the sternum and the other electrode pad comprising 3 electrodes is placed across the right midaxillary line at the level of the xiphoid.
- Based on impedance measurement.
- RVM displays minute ventilation, tidal volume, respiratory rate, respiratory volume curve, and trends.

**Figure 1.** Standard electrode placement. Electrode strip containing 3 electrodes is placed between sternal notch and xiphoid. Separate pad containing an additional 3 electrodes is placed along the right midaxillary line at the level of the xiphoid.
Standardized Hourly Rounding

• 6 month study in 2 32-bed cardiovascular surgery units; 1 received the intervention.
• Significant reductions in call light use and the number of steps taken by the day-shift staff on the intervention unit.
• Differences in the number of patient falls, 30-day readmission rates, and patients’ perception of care were not significant.

Krepper, J for Healthcare Quality 2012:62
Additional Monitoring

• NIV: tidal volume, respiratory rate, ventilating pressures, FIO$_2$, alarm output to nurse call

• CPAP: AHI, hours of use, periodic breathing, pressure
Appropriate monitoring
Identification of clinical deterioration and timely intervention

Too little monitoring
Missed events

Too much monitoring
Cost: equipment and training
Alarm fatigue
Over-diagnosis
False Positive = Alarms

• Assume monitor has a true positive rate of 95% (false positive rate 5%).
• In the presence of 2 monitors, the probability of both monitors giving a true positive is $0.95^2 = 90\%$.
• In the presence of 20 monitors, the true positive rate is $0.95^{20} = 0.36 = 64\%$ probability of at least one monitor giving a false positive alarm.

Hess, Respir Care 1990;35:482
If they are not properly managed, alarms can compromise patient safety.
When to Monitor (Technology)
When to Start; When to Stop

- **Disease**: COPD, OSA, CHF, etc.

- **Procedure**: post op, procedural sedation, etc.

- **Therapy**: $O_2$, opioid, CPAP, NIV

Is there a biomarker?
Therapy (oxygen, opioid, CPAP, NIV)

Procedure (post-op, procedural sedation)

Disease with high risk (OSA, COPD, CHF)

How?
Current And Future Objective Monitors Outside The ICU

- Monitoring is often implemented based on face validity and what can be monitored.
- The decision to monitor should be based on clinical indications.
- Clinical trials are necessary to determine the appropriate role of monitoring?
- Perhaps we are not using the technology appropriately? Trends versus spot checks.
- What is an appropriate sensitivity/specificity?
Which Comes First?

Good technology exists ... The challenge is to use it wisely.
When technology becomes master, we get to disaster faster.

Piet Hein
How do we capture the “eyeball test” into technology?

The role of the “human touch” in use of technology