Methods for Analyzing Clinical Utility of Respiratory Rate Monitors

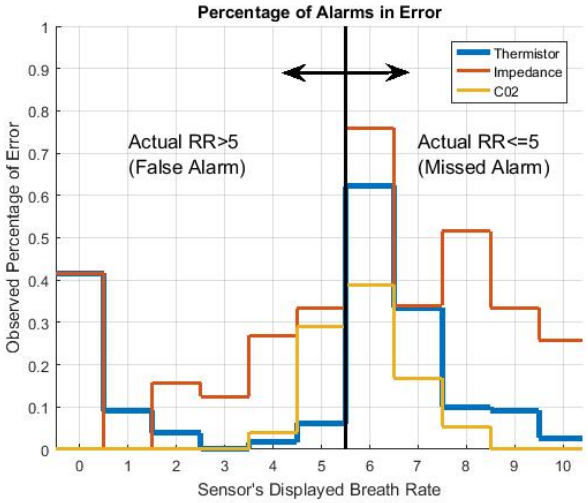
Authors: Sean Ermer B.S., Lara Brewer Ph.D, Joe Orr, Ph.D, Ken Johnson M.D, M.S.
University of Utah

Introduction: With growing concern over opioid induced respiratory depression in the postoperative period, many have begun discussing continuous respiratory monitoring as a means of mitigating adverse respiratory events. Several different respiratory monitoring methods have been presented in the literature, and yet none have emerged as a standard for non-intubated respiratory monitoring. One reason for a lack of standard for non-intubated respiratory monitoring comes from the difficulty in defining what statistical analysis could define a respiratory monitor as 'adequate' for clinical use. This research project focused on potential methods for discussing viability of monitors for use in patients with low respiratory rates. With that in mind, data were specifically analyzed from periods of low respiratory rate with statistics that identify how often a clinical monitor might incorrectly influence a clinical decision.

Methods: With IRB approval, data were collected from 26 volunteers who were administered target controlled infusions of Remifentanil and Propofol in order to induce low respiratory rates. Data were collected from a suite of sensors which were analyzed using a standard breath detection algorithm. Breath rates derived from a capnometer, oronasal thermistor, and impedance respiratory sensor were compared against breath rates derived from the reference standard of respiratory inductance plethysmography bands at low breath rates (RR<=10). A Bland-Altman analysis was performed for each signal. This was followed by an analysis which calculated the probability of alarm error (either a false positive or false negative message) for hypopnea (defined as RR<=5).

Results: 407 minutes of data were collected and analyzed. The results of the Bland-Altman analysis and percentage of error based on the collected data are also reported in the figure below.

	Capnography	Impedance	Thermistor
Bias (BPM)	0.18	0.64	0.51
Std (BPM)	1.18	3.96	2.09
Upper 95% Confidence Interval	2.5	8.39	4.61



(BPM)			
Lower 95% Confidence Interval (BPM)	-2.13	-7.12	-3.58

A **B**

Figure 1: Panel A: Bland-Altman statistics for all three sensors. Values are reported as breaths per minute and are calculated as 'test-signal' minus 'reference signal'. For example, a positive bias means too many breaths were detected by the test signal. Panel B: The observed percentage that a given sensor's alarm message was in error about the presence of hypopnea (RR<=5). For example, roughly 40% of the time that the capnometer reported a breath rate of 6, the true breath rate was 5 or lower. Similarly, roughly 7% of the time the thermistor reported a breath rate of 5, the true breath rate was 6 or higher.

Discussion: Most publications attempting to evaluate different signals for clinical use focus on Bland-Altman statistics such as bias and standard deviation. While useful, these statistics don't always tell the whole story with respect to clinical decision making. While it's useful to know that a monitor has a 95% confidence interval of ±2 BPM, this information may not be impactful at large respiratory rates (RR>12) and may not be specific enough at low respiratory rates. For example in the figure above, one can see how assuming a normal distribution might lead to incorrect diagnoses; All three monitors are much more likely to have a false negative error than a false positive one. An analysis such as the one proposed here could be used to better inform clinicians about when it is safe to trust the reported value or displayed message on a given monitor. In the case of the capnogram, the only errors occur within -2 to +3 breaths of the hypopnea threshold, and outside of ±1 breath of the threshold the number of errors decrease drastically.