Comparison of Hypopneic Respiratory Rates Reported from Seven Sensors in Non-Intubated, Sedated Volunteers

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Introduction: Growing concern over opioid-induced respiratory depression in the post-operative environment has led many experts and consensus guidelines to suggest that all patients receiving opioids be monitored for respiratory rate. Though many potential monitors have been evaluated in the literature, differences in study populations, algorithms, and statistical methods make comparisons between these monitors difficult. To date, no true standard for non-intubated respiratory rate monitoring has emerged in the clinical setting. The goal of this research project was to collect respiratory rate data from a wide set of sensors and perform a comparative analysis while holding as many variables constant as possible. Specifically, we aimed to analyze these sensors' performance in the hypopneic range in order to best understand how they might detect adverse events.

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 single, custom breath detection algorithm. Breath rates derived from a capnometer, oronasal thermistor, nasal pressure transducer, abdomen accelerometer, microphone, photoplethysmogram, 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 BPM). A Bland-Altman analysis was performed for each signal.

Results: 407 minutes of data were collected and analyzed. The results of the Bland-Altman analysis are reported in the table below.

	Accelerometer	Nasal Pressure	Thermistor	Impedance	Capnometer	PPG	Microphone
Bias (BPM)	0.10	0.00	0.50	0.60	0.20	0.40	0.20
Std (BPM)	1.08	2.49	2.07	3.92	1.17	3.03	2.15
Upper 95% Confidence Interval (BPM)	2.20	4.90	4.60	8.30	2.50	6.30	4.40
Lower 95% Confidence Interval (BPM)	-2.00	-4.90	-3.60	-7.10	-2.10	-5.50	-4.00

Table 1: Bland-Altman statistics for seven sensors. Values are reported as breaths per minute and are calculated as 'test-signal' minus 'reference signal'. For example, a positive bias means that the test signal identified more breaths than the reference signal, on average. 407 minutes of data were used for this analysis.

Discussion: Through evaluating all seven sensors using the same methods—including the same algorithm, study population, and statistical analyses—we can better compare reported respiratory rate. The abdomen accelerometer and capnometer had the best agreement with the reference. The impedance and PPG sensors had the lowest agreement, as both were subject to a high degree of cardiac noise. Though the nasal pressure and thermistor signals generally showed a high signal-to-noise ratio, they also occasionally suffered from overall low signal amplitude which led to their middling results. The primary hurdle with the microphone was the biphasic nature of the signal which would occasionally cause one breath to be double counted. Overall, an understanding of how these devices perform in the low respiratory rate range may help influence clinical decisions about patient monitoring in the post-operative period.