Comparison of a Wide Respiratory Rate Range Reported from Seven Sensors in Non-Intubated, Spontaneously Breathing 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 described in the literature, in-depth details regarding the breath detection algorithms are usually scarce. This dearth of information makes comparisons between sensors difficult. The goal of this research project was to create a single algorithm capable of identifying breaths in a multitude of potential monitors. The respiratory rate range analyzed included apnea (zero breaths per minute) to normal (21 breaths per minute) ranges.

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 (RR range: 0-21 BPM). A Bland-Altman analysis was performed for each signal.

Results: 877 minutes of data were collected and analyzed (For the case of the microphone for which 828 minutes were analyzed). The results of the Bland-Altman analysis are reported in the table below. Of the data analyzed, 407 minutes were at a respiratory rate of 10 BPM or fewer.

	Accelerometer	Nasal Pressure	Thermistor	Impedance	Capnometer	PPG	Microphone
Bias (BPM)	-0.30	-0.40	-0.20	-1.40	0.00	-2.00	-1.70
Std (BPM)	1.89	2.76	2.34	4.95	1.25	4.87	4.52
Upper 95% Confidence Interval (BPM)	3.40	5.00	4.40	8.30	2.50	7.50	7.20
Lower 95% Confidence Interval (BPM)	-4.00	-5.80	-4.80	-11.10	-2.50	-11.50	-10.60

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. 877 minutes of data were used for this analysis, except in the case of the microphone where some data became corrupted during the course of the study. As a result, 828 minutes of data were used for that comparison. PPG indicates photoplethysmogram.

Discussion: Creating a single algorithm to identify breaths across multiple signals has both advantages and disadvantages. The primary advantage is that it allows us to perform a more constant comparison among signals by holding algorithm performance constant. It also allows us to analyze a large number of signals relatively quickly instead of developing individual algorithms for each. On the other hand, the algorithm may not be perfectly suited for all signals. The PPG and microphone for example have fundamentally different signal morphologies from the rest. Overall, the results were in line with our expectations. The capnometer and abdomen accelerometer had the best agreement with the reference signal. Most signals displayed a negative bias because sections of low signal amplitude (poor signal quality) in a given signal will heavily underreport respiratory rate. Signals for which this was more common had more negative bias compared to the others. Ignoring these sections, most signals showed relatively standard distributions with low bias to the reference signal.