Analysis of Central and Obstructive Apnea Detection Using Combination Sensors

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Introduction: The first 24 hours after surgery represent a high-risk period for adverse respiratory events in patients being treated for postoperative pain [1]. Despite these patients' high propensity for respiratory depression, the current standard of care for postoperative monitoring is intermittent spot-checking of respiratory rate and/or pulse oximetry performed by hospital staff. In addition, traditional spot-checking monitors do not differentiate between central and obstructive apnea, which is critical for adjusting care to keep the patient safe (e.g., adjust drug levels or provide CPAP, respectively). We combined data from novel sensors placed above and below the point of obstruction—the trachea—in order to differentially identify both central and obstructive apnea, and compared each sensor combination's effectiveness in detecting each event type.

Methods: With IRB approval, fifteen healthy volunteers (Ages 19-41, BMI 20.9-28.4) were administered target-controlled infusions of remifentanil (0.75-5 ng/mL) and propofol (0.75-5 mcg/mL) to achieve increasing levels of sedation and induce apnea, hypopnea, and airway obstruction—both individually and in combination. Respiratory data were collected from nasal pressure (1 INCH-D-4V, All Sensors, Morgan Hill, CA), nasal/oral thermistor (Disposable Adult Airflow Sensor, Braebon Medical Corporation, Kanata, ON, Canada), capnometry (LoFlo, Philips, Wallingford CT), respiratory inductance plethysmography (Q-RIP, Braebon Medical Corporation, Kanata, ON, Canada), impedance respiratory rate (Datex Ohmeda, GE Healthcare, Louisville, KY), and abdomen accelerometer sensors (ADXL345, Analog Devices, Norwood, MA). During the study, periods of central and obstructive apnea were identified by capnography and respiratory inductance plethysmography data in combination with comments from two concurring anesthesiologists who had access to breath sounds recorded at the trachea and direct auscultation. We identified thirty epochs each of apnea, airway obstruction, and normal breathing. The duration of normal breathing epochs was defined as the average length of the apneic periods. Data recorded from sensors placed at the head and the chest were then combined to classify the events as normal, obstructive apnea or central apnea. If breaths were identified at the chest with no matching breaths at the head, the epoch was classified as obstructive apnea. If neither sensor identified a breath in the last thirty seconds, the epoch was classified as central apnea. We calculated sensitivity and specificity for each sensor combination.

Results: The results are provided in Table 1.

Sensor Combination		Obstructive Apnea		Central Apnea	
Body Signal	Head Signal	Sensitivity	Specificity	Sensitivity	Specificity
Accelerometer	Nasal Pressure	0.933	1.000	1.000	1.000

Accelerometer	Thermistor	0.800	0.867	0.700	0.867
Impedance RR	Nasal Pressure	0.833	0.967	0.733	0.967
Impedance RR	Thermistor	0.267	0.933	0.500	0.933

Table 1. Sensitivity and specificity for event detection by each sensor combination.

Discussion: The combination of nasal pressure and chest accelerometer sensors showed the best sensitivity and specificity for differentially identifying central and obstructive apneic periods. Combining these cost-effective sensors may help improve postoperative care by informing the clinician about the type of ventilation problem so that they may treat it more efficiently. In the future, we plan to include a wider array of sensors, and expand the 'gold standard' data set to include all events during the study.

[1] Taylor, Shiv, Orlando C. Kirton, Ilene Staff, and Robert A. Kozol. "Postoperative Day One: A High Risk Period for Respiratory Events." *The American Journal of Surgery* 190, no. 5 (November 2005): 752–56. doi:10.1016/j.amjsurg.2005.07.015.