Respiration Signals from Photoplethysmography
Nilsson L.M. *Anesth Analg*. 2013 Feb 28

Pulse oximetry is based on the technique of photoplethysmography (PPG) wherein light transmitted through tissues is modulated by the pulse. In addition to variations in light modulation by the cardiac cycle, the PPG signal contains a respiratory modulation and variations associated with changing tissue blood volume of other origins. Cardiovascular, respiratory, and neural fluctuations in the PPG signal are of different frequencies and can all be characterized according to their sinusoidal components. PPG was described in 1937 to measure blood volume changes. The technique is today increasingly used, in part because of developments in semiconductor technology during recent decades that have resulted in considerable advances in PPG probe design.

Artificial neural networks help to detect complex nonlinear relationships and are extensively used in electronic signal analysis, including PPG. Patient and/or probe-tissue movement artifacts are sources of signal interference. Physiologic variations such as vasoconstriction, a deep gasp, or yawn also affect the signal. Monitoring respiratory rates from PPG are often based on respiratory-induced intensity variations (RIIVs) contained in the baseline of the PPG signal. Qualitative RIIV signals may be used for monitoring purposes regardless of age, gender, anesthesia, and mode of ventilation. Detection of breaths in adult volunteers had a maximal error of 8%, and in infants the rates of overdetected and missed breaths using PPG were 1.5% and 2.7%, respectively. During central apnea, the rhythmic RIIV signals caused by variations in intrathoracic pressure disappear. PPG has been evaluated for detecting airway obstruction with a sensitivity of 75% and a specificity of 85%.

The RIIV and the pulse synchronous PPG waveform are sensitive for detecting hypovolemia. The respiratory synchronous variation of the PPG pulse amplitude is an accurate predictor of fluid responsiveness. Pleth variability index is a continuous measure of the respiratory modulation of the pulse oximeter waveform and has been shown to predict fluid responsiveness in mechanically ventilated patients including infants. The pleth variability index value depends on the size of the tidal volume and on positive end-expiratory pressure.

In conclusion, the respiration modulation of the PPG signal can be used to monitor respiratory rate. It is probable that improvements in neural network technology will increase sensitivity and specificity for detecting both central and obstructive apnea. The size of the PPG respiration variation can predict fluid responsiveness in mechanically ventilated patients.