

Monitoring respiration rate in PACU patients using the plethysmogram from a pulse oximeter

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Introduction Post-operative patients with undiagnosed obstructive sleep apnea are at risk of sudden respiratory failure after receiving anesthesia because of repressed respiratory and hemodynamic responses^[1]. While all patients have their oxygen saturation automatically monitor in the Post Anesthesia Care Unit (PACU), few have their respiration rate monitored. The goal of our study is to develop algorithms that reliably extract the respiration rate from a standard pulse oximeter signal. The pulse oximeter is an inexpensive and widely available device that measures the pulsatile waveform, the plethysmogram (PPG), and oxygen saturation.

The PPG measured by the pulse oximeter, commonly referred to as the “pleth waveform”, is an indirect measurement of blood volume under the sensor. The temporal behavior of this signal is influenced both by the cardiac and respiratory cycles. Respiratory induced variations (RIV) in PPG amplitude have been documented and associated with airway obstruction, hypovolemia, and hypotension^[4,5,6]. These studies were qualitative, and often relied on spectral analysis of the PPG. However, to the best of our knowledge, previous research has not examined the effect of the respiratory cycle on the pulse morphology.

The pulse morphology is obtained using a mixed-state feature extractor based on previous work on sequential state estimation^[3]. This feature extractor allows us to obtain statistics about each individual pulse, including pulse height, width, area, rise and fall time. Our experimental results demonstrate that these features show measurable variations due to respiration, and are a reliable measure of respiration rate.

Experimental Procedure With IRB approval, six patients (ASA Class 1 and 2) were monitored for up to an hour during their stay in the PACU. The patients were monitored using a Datex Ohmeda bedside monitor, a Nonin forehead reflectance pulse oximeter (pulse ox), and a digital video recorder. The respiration rate was manually extracted from the video recording by observing the rise and fall of the chest.

We chose the forehead location because other studies suggest that this is the best location for detecting respiratory variations in the pleth waveform [2]. Data from the pulse oximeter was pre-processed using standard Nonin hardware (AC coupled and bandpass filtered).

Results The respiratory rates obtained from our feature extraction software were compared to the respiratory rates from the video. As shown in Figure 1 the pulse height, the difference between the rise and fall time and the instantaneous heart rate all provide robust statistics for estimating instantaneous respiration rate. However, during brief periods of movement, talking, or change in pose, motion artifacts obscure the pulsatile component of the signal. Also periods of low perfusion gives a small pulse amplitude, less than ten units, and results in immeasurable RIV; very shallow breathing can also result in very small RIV. Subsequent work has shown that when excessive pressure is used to hold the pulse ox to the forehead the PPG is suppressed and will result in an immeasurable RIV.

Conclusion Respiration rate can reliably be estimated from the PPG signal of a properly mounted pulse oximeter. We expect future version of our algorithm to calculate a confidence interval for the respiration rate measurements based on the signal quality.

References

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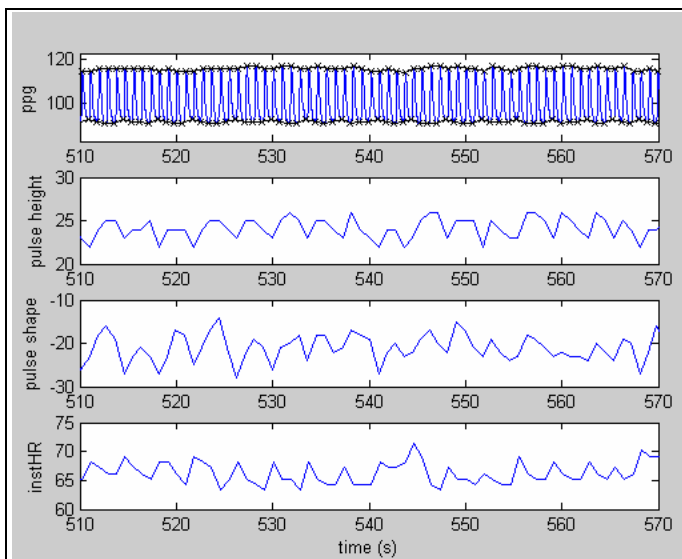


Figure 1. Respiratory induced variations in the plethysmogram for a one minute time segment are shown to occur in the waveform envelope, pulse height, pulse shape (the difference between the pulse rise and fall time) and the instantaneous heart rate calculation in beats per minute (bpm). Analysis of chest motion from the record video shows an average of 18 breaths per minute during this period. Our feature detection software found 17 RIVs for three of the four features.