Impact of Incentive Spirometry (IS) Breathing on Infra Red Finger Photoplethysmographic (IR-PPG) Waveform Provided by the Sentec Digital Monitor

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Introduction: Pulse oximetry is the most widely used application of the optical technique photoplethysmography (PPG). It has recently been shown that pulse oximetry has potential for the assessment of fluid responsiveness during mechanical ventilation.[1] During spontaneous breathing, assessment of fluid responsiveness still continues to be a challenge as dynamic indices have been unable to detect hypovolaemia.[2] Commercially available pulse oximeters provide waveforms that are filtered (high pass) and are dynamically amplified (auto-center & auto-gain). In this study, we sought to explore changes in the raw finger PPG signal (infrared - IR) waveform provided by a SenTec® Digital Monitor (www.sentec.ch) during Incentive Spirometry (IS) breathing. This was done in the hopes of developing a better understanding of the physiology of cardiopulmonary interaction. We see this as the first step in solving the dilemma of assessment of fluid responsiveness in spontaneous breathing subjects. We assume that the less filtered IR PPG signal will reveal more of the normally filtered venous component of the PPG waveforms (DC component), and thus will allow for the comparison of the impact of the IS on both the IR-PPG waveforms and the peripheral venous pressure (PVP) waveforms. Incentive Spirometry breathing will increase the lung volume quickly. It results in a reduction in RA preload, as well as an increase in afterload of the right and left ventricle, that appear to have characteristics similar to positive pressure ventilation.[3]

Methods: With IRB approval, 11 healthy volunteers were recruited. The SenTec sensor was applied to the finger and the PVP signals were recorded from a transduced intravenous catheter at the hand at 100 Hz with GE S/5 Collect system and analyzed with LabChart 7.3.7 (ADInstruments). Each subject was asked to take deep breaths through the incentive spirometer for 12 breaths (encourage the patients to move all 3 balls). The height of both IR-PPG and PVP waveforms was measured. Data were summarized as mean ±SD and analyzed using a paired t-test. P value <0.05 were considered statistically significant.

Results: The IS breathing showed significant increase in the amplitude of the IR-PPG and PVP (8828±4098 vs.17434±9202) and (1.3±0.4 vs.4.7±2.7) respectively as shown in figure 1. The percent change of IR-PPG and PVP height increased respectively by 97%% and 269% during IS breathing respectively.

Conclusion: The cardiopulmonary interaction of IS showed significant increase in the amplitude of the IR-PPG. This confirms that the raw PPG signals reflect more of the venous component of the waveform. Figure (1-a) shows the effect of the Incentive Spirometry on the PVP waveforms with the creation of a “shock wave” down the arm that resulted in an increase in the PVP and this coincides with changes of the IR-PPG waveforms. This leads to the intriguing potential for measurement of venous compliance via the measurement of changes in both pressure and volume of the peripheral venous system.

References:

1. Anesth. Analg. 2006; 103 1478–84
2. .Physiol. Meas. 31 (2010) 953–962
3. Sensor 2012;12 (2)2236-54

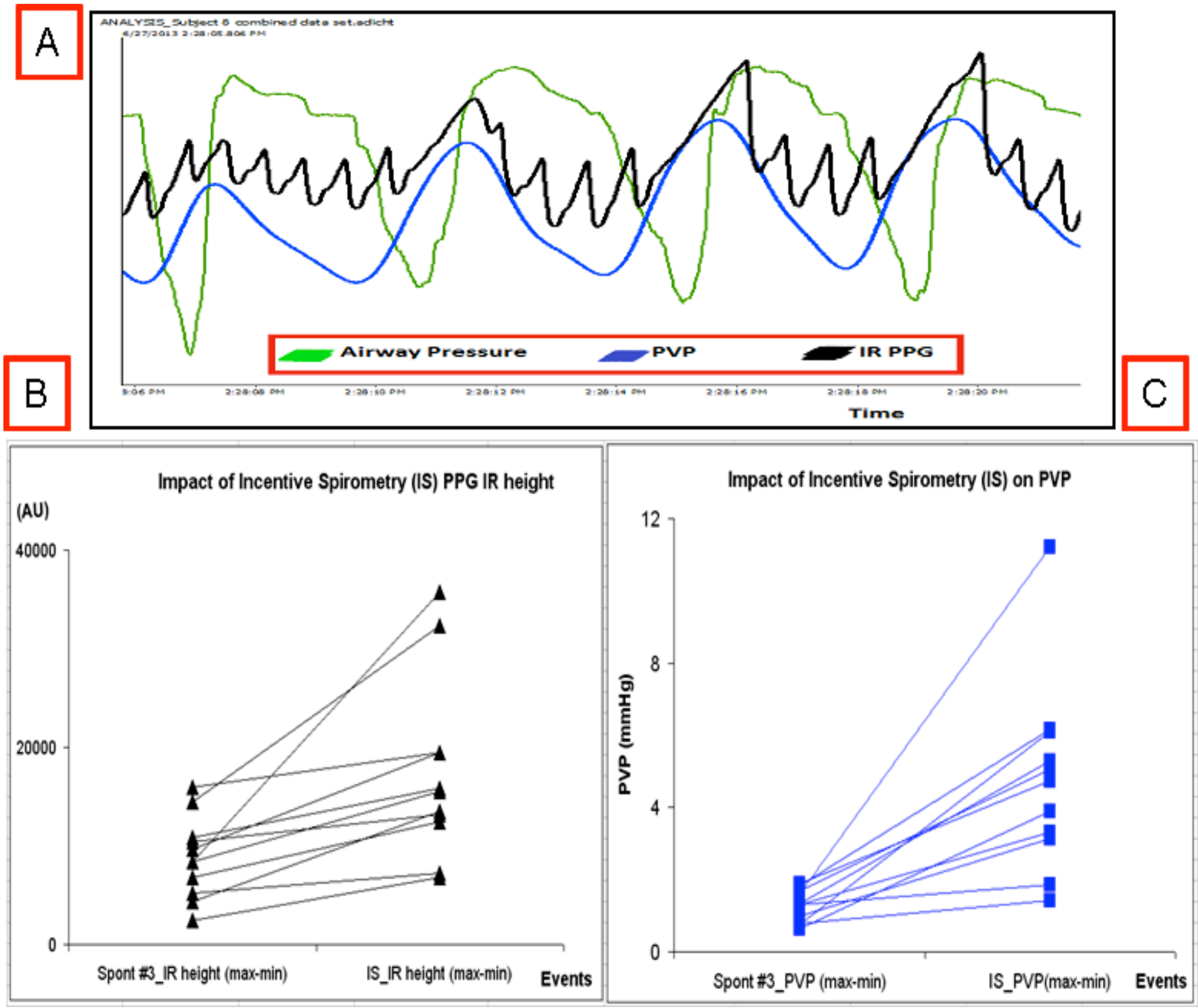

Figure (1): (A): Raw data of airway pressure, IR_PPG and peripheral venous pressure (PVP) during Incentive spirometry; notice the concordance of the increase in IR- PPG and PVP during inspiration (down deflection of the airway pressure). (B): The impact of incentive spirometry (IS) on IR-PPG. (C): The impact of IS on the on PVP.