Comparison of Different Methods of Frequency Analysis of the Clinical Waveforms

Authors: Aymen Alian, MD, Kirk Shelley, MD, PhD; Department of Anesthesiology, Yale University School of Medicine, New Haven, CT

Introduction: Frequency analysis of the pulse oximeter waveform (PPG) is a powerful method used to detect changes in the waveform at the respiratory and cardiac frequencies.[1] It is less prone to artifact, compared to time domain techniques, because it allows for examination of physiologic phenomena specifically at the respiratory frequency. Different types of frequency analysis include amplitude, amplitude density (which accounts for the size of the window), power (square of the amplitude) and power density measurement. One of the most frequently used methods of frequency analysis is the calculation of the power spectrum. This is used to improve the signal to noise ratio. This is done at the expense of low amplitude background signals (such as respiration when compared to the cardiac modulations). This abstract examines some of the technical aspects of these types of calculations.

Methods: Finger PPG and airway pressure were recorded at 100 Hz from operating room clinical monitors (GE; Fairfield, CT) with a data acquisition system (Collect 5/S – GE; Fairfield, CT). We used LabChart 7.37 (ADInstruments, Boulder CO) to analyze these waveforms as shown in figure (1). Frequency analysis of the PPG waveforms was performed using amplitude modulation of PPG (PPG AC) and baseline modulation (PPG DC). Fast-Fourier Transform (FFT) with a spectrum view setting as shown in figure (1), [spectrum, 4K (40 second@100 Hz) Hamming window, amplitude density (AD), 93.75% window overlap] over 3 minute windows. Modulations of the PPG waveform at respiratory and cardiac pulse frequency were isolated where the respiratory frequency was defined as the same frequency as the airway pressure waveform and cardiac pulse frequency was defined as the highest peak between 1-2.5 Hz. The strength of the waveform's modulations was measured as either the peak value of amplitude, amplitude density, power or power density or the area under the curve of the corresponding frequency. Data presented as mean ± SD, paired t-test was used and P value <0.01 was considered significant.

Results: Frequency analysis of the PPG was performed on 30 different waveform segments. In table 1-A, there was a significant increase in the peak values of PPG DC% and AC% amplitude and amplitude density when compared to the peak values of power and power density. In table 1-B; there was a significant increase in peak value when compared to the area under the curve for the amplitude, amplitude density, power and power density of PPG DC% and AC%.

Conclusion: The peak value of amplitude density (AD) appeared to be the most sensitive measurement of the respiratory modulation in the PPG. We attributed this to a number of factors. Amplitude measurement (as opposed to Power) assures that the respiratory signal does not become overpowered by the cardiac signal in the PPG. A density measurement corrects for window size and allows for the comparison of uneven windows. In this study it did not appear to impact on the sensitivity of the method. Finally, the peak measurement,

when compared to area, appears to be superior because of its ease of calculation and its sensitivity to subtle changes.

References: 1. JCMC 2011;25(6); 387-396

Figure (1):

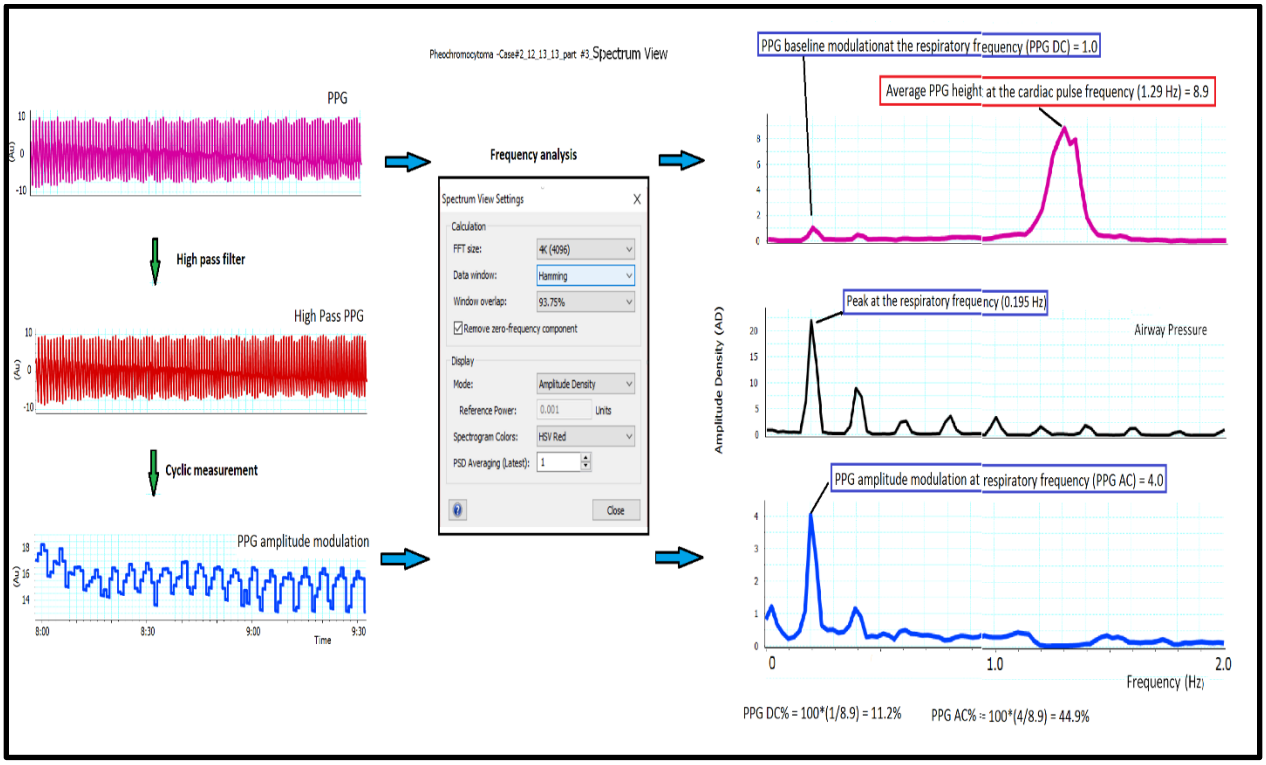

Table (1):

A

Peak value	Amplitude	Power	Amplitude Density (AD)	Power Density (PD)
PPG DC%	5.2 (2.6)	0.34 (0.37)	5.2 (2.7)	0.34 (0.37)
p value		**<0.01**		**<0.01**
PPG AC%	19.6 (10.6)	4.96 (5.46)	19.7 (10.7)	4.81 (5.51)
p value		**<0.01**		**<0.01**

B

PPG	Variables	**Peak value**	**Area**	*P value*
PPG DC%	Amplitude	5.2 (2.6)	3.2 (1.5)	**<0.01**
	Amplitude Density (AD)	5.2 (2.7)	3.1 (1.4)	**<0.01**
	Power	0.34 (0.37)	0.19 (0.18)	**<0.01**
	Power Density (PD)	0.34 (0.37)	0.19 (0.19)	**<0.01**
PPG AC%	Amplitude	19.6 (10.6)	11.7 (5.1)	**<0.01**
	Amplitude Density (AD)	19.7 (10.7)	11.7 (5.1)	**<0.01**
	Power	4.96 (5.46)	2.72 (2.79)	**<0.01**
	Power Density (PD)	4.81 (5.51)	2.65 (2.75)	**<0.01**