IMPACT OF CENTRAL HYPOVOLEMIA ON PHOTOPLETHYSMOGRAPHIC WAVEFORM PARAMETERS IN HEALTHY VOLUNTEERS. PART 1: TIME DOMAIN ANALYSIS

Aymen A. Alian, MD; Nicholas J. Galante, BS; Salman Haider, MD;
David G. Silverman, MD; Kirk H. Shelley, MD, PhD
Department of Anesthesiology, Yale University School of Medicine, New Haven, Connecticut

Introduction: Lower body negative pressure (LBNP) is an excellent model for hypovolemic circulatory stress[1], since it rapidly decreases central blood volume by sequestering blood in the lower extremities through application of negative pressure around the legs and abdomen. We hypothesize that during a hypovolemic challenge such as Lower body negative pressure (LBNP), a preservation of ear PPG characteristics and a decrease in finger PPG characteristics will be seen. Our study sought to explore changes in PPG waveform parameters; height, peak area, width 50, maximum and minimum slope (figure 1) and to determine which components of the PPG waveform could serve as early indicators of reduction in central blood volume during LBNP in spontaneously breathing volunteers. Previous work has demonstrated a differential vasoconstrictive response in the finger vs. ear during cold pressor testing[2] , the decreased height of the finger was attributable to greater adrenergic activity in this region.

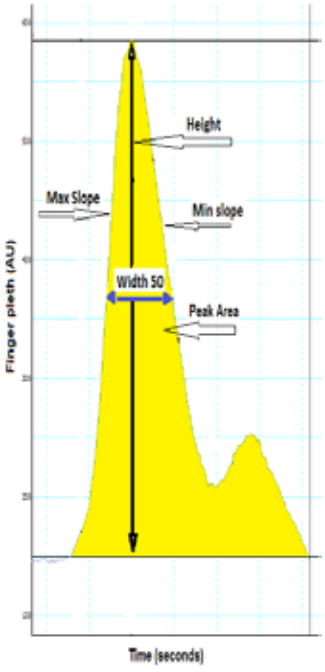

Figure 1

Methodology: With IRB approval, eleven healthy volunteers age 24-37 underwent a lower body negative pressure (LBNP) protocol consisting of a 3 min baseline and successive 3 min intervals at baseline, 30, 75 and 90 mm Hg (or until the subject became symptomatic). Subjects were monitored with finger and ear pulse oximeter probes, ECG, and finger arterial blood pressure monitor. Data recorded and analyzed with commercially available software (Chart, ADInstruments). Data are presented as median and inter-quartile range (IQR). Friedman ANOVA and Wilcoxon test were used to identify changes in hemodynamic and plethysmographic variables, $P < 0.017$ was considered statistically.

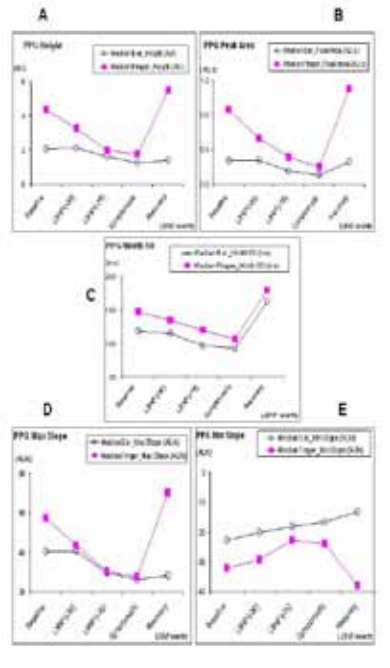

Figure 2

Finger Plethysmography					
Parameters	Baseline	LBNP 30	LBNP 75	Symptomatic	Recovery
Height (AU)	4.33(2.87)	3.28(2.23)*	1.97(1.52)*	1.76(2.2)*	5.78(2.5)
% change from baseline		-25.6%	-54.5%	-59.4%	26.1%
Peak area (AU.s)	0.86(0.52)	0.55(0.36)*	0.31(0.22)*	0.198(0.28)*	1.1(0.58)
% change from baseline		-35.4%	-63.9%	-76.9%	28.1%
Width 50 (ms)	116.8(17.8)	134.2(7.4)*	120.1(12.1)*	106.6(15.4)*	179.3(18.2)**
% change from baseline		-3.6%	-18.2%	-27.4%	22.1%
Max slope (AU/s)	57.25(38.03)	43.81(26.4)*	30.61(21.2)*	27.72(30.04)*	70.04(27.6)
% change from baseline		-25.5%	-46.5%	-51.6%	22.5%
Min slope(AU/s)	-32.26(25.9)	-29.58(16.5)	-22.79(18.8)	-23.96(26.6)	-58.2(35.5)
% change from baseline		-9.1%	-29.4%	-25.7%	58.5%
Ear Plethysmography					
Parameters	Baseline	LBNP 30	LBNP 75	Symptomatic	Recovery
Height (AU)	2.05(0.77)	2.11(0.64)	1.59(0.55)*	1.24(0.74)*	1.4(0.63)**
% change from baseline		3.1%	-22.2%	-39.5%	-31.4%
Peak area (AU.s)	0.27(0.1)	0.28(0.13)	0.15(0.7)*	0.10(0.11)*	0.26(0.12)
% change from baseline		5.5%	-44.2%	-61.6%	-4.2%
Width 50 (ms)	118.2(16.2)	115.1(13.2)	96.7(12.9)*	92.6(20.9)*	162.1(70.35)
% change from baseline		-2.6%	-18.2%	-21.4%	37.1%
Max slope (AU/s)	40.38(14.2)	41.67(9.2)	29.78(12.3)*	26.33(8.1)*	28.18(8.8)
% change from baseline		0.7%	-26.2%	-34.9%	-30.2%
Min slope (AU/s)	-22.76(11.6)	-20.15(9.4)	-18.06(6.7)	-16.72(3.5)	-13.22(3.7)
% change from baseline		-11.4%	-20.6%	-26.8%	-41.9%

Table 1

Results: There were no significant changes in the blood pressure variables at 30 mmHg, but at and beyond 75 mmHg, the decreases in systolic, mean and pulse pressure were significant as the increase in diastolic pressure. Heart rate increased significantly by 30 mmHg, reaching a maximum of 75.4% above baseline at symptomatic phase. Finger PPG height, peak area, width 50 and maximum slope decreased significantly at LBNP 30 mmHg and reached declines of 59.4%, 76.9%, 27.4% and 51.6%, respectively, during the symptomatic phase (table 1). Ear PPG height, peak area, width 50 and maximum slope did not change significantly at LBNP 30 mmHg, but declined significantly at 75 mmHg. During the symptomatic phase, the respective declines reached 39.3%, 61.0%, 21.4% and 34.9% (figure 2).

Discussion: Systolic, diastolic and mean finger arterial blood pressures together with pulse pressure were well preserved. While finger plethysmographic waveforms characteristics showed significant reduction ($p < 0.017$); peak area (38.4%), height (25.6%) max slope (23.5%) and width 50 (8.6%). On the other hand, ear plethysmographic waveform characteristics were not significantly changed. This suggests that finger plethysmographic waveform parameters (height, peak area, width 50, maximum and minimum slope) might be used as a monitor of sympathetic tone. On the other hand, the ear plethysmographic waveform, because of its location, appears to be more reflective of central hemodynamic changes.

Conclusion: PPG waveform parameters may prove to be sensitive and specific as early indicators of blood loss. These PPG changes were observed before profound decreases in arterial blood pressure. The relative sparing of central cutaneous blood flow is likely parasympathetic in nature when compared to a peripheral site where there is high sympathetic tone and vasoconstriction

References:

1. J Gravit Physiol. 2001;8((2)):1-14., 2. Anesth Analg 2001; 92- 1483-86