

Study of the Finger PPG Width During Lower Body Negative Pressure

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Introduction: The pulse oximeter waveform reflects volume changes in skin microcirculation. The finger is a more useful and responsive site when compared to the ear when measuring the activity of the sympathetic system.⁽¹⁾ The pulse width is more sensitive than other parameters on the PPG waveform in detecting changes in systemic vascular resistance.⁽²⁾ Blood pressure measurements and heart rate (HR) are commonly used for the assessment of hypovolemia.⁽³⁾ Lower body negative pressure (LBNP) creates a reversible hypovolemia by sequestering blood in the lower extremities. This study sought to determine if finger PPG width, SBP, DBP, MAP and HR measurement will be different between symptomatic (low tolerance to hypovolemia) and asymptomatic (high tolerance to hypovolemia) subjects during LBNP.

Methods: With IRB approval 17 subjects underwent progressive LBNP. Heart rate (HR), continuous noninvasive arterial pressure (CNAP) to determine SBP, DBP and MAP, and finger pulse oximeter were monitored. These parameters were measured during baseline, -30, -45, -60 and -75 mmHg LBNP. The width of the PPG waveform was calculated using Labchart 7. Subjects were divided into low tolerance (LT) and high tolerance (HT) groups based on the development of symptoms of hypovolemia (diaphoresis, lightheadedness, nausea) during progressive LBNP. Subjects that developed symptoms at LBNP of -60 mmHg were assigned to the (LT) group and subjects who did not develop symptoms or developed symptoms at LBNP lower than -75 mmHg were assigned to the (HT) group (high tolerance to hypovolemia). PPG, SBP, DBP, MAP and HR percent change was calculated using: percent change from baseline = $100 * ((\text{LBNP value} - \text{baseline value}) / \text{baseline value})$ and t-test was used. Data was reported as mean \pm SD and $p < 0.05$ was considered significant.

Results: 2 out of the 17 subjects were excluded from the study due to insufficient data, 9 out of 15 subjects were assigned to the (LT) group and 6 subjects to the (HT) group. Finger PPG width showed significant difference between (LT) and (HT) group at LBNP of -45 and -60 mmHg, as shown in (table 1). There were no significant differences in MAP and SBP variability between (LT) and (HT) groups at any phase during LBNP, results summarized in (table 1). Heart rate showed significant difference between (LT) and (HT) group at LBNP -60 mmHg, as shown in (table 1). Changes from baseline for finger PPG width, blood pressure and heart rate are shown in figures (1 –A) and (1-B) for (LT) and (HT) groups respectively.

Discussion: Early recognition of hypovolemia can be complicated by compensatory mechanisms such as systemic vasoconstriction and blood flow redistribution. Our data shows that SBP and MAP were maintained even with ~ 1300 cc blood loss (LBNP -60 mmHg). Tachycardia, the first clinical sign of significant hypovolemia, was only seen at ~ 1000 mL blood loss (LBNP -45 mmHg), and there were no changes in blood pressure detected. On the other hand, the finger PPG width showed significant reduction at LBNP -45 and -60 in the LT group while no changes in blood pressure were detected.

Conclusion: the PPG waveform width could be a reliable tool for early detection of hypovolemia.

References:

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Table 1: summarized the average ±(SD) of finger PPG width, SBP, DBP, MAP and HR during different phases of LBNP (baseline, -30 mmHg, -45 mmHg, and -60 mmHg). LT: low tolerance for LBNP (symptomatic at LBNP -60 mmHg), HT: high tolerance for LBNP (Asymptomatic at LBNP = -60 mmHg). SBP: Systolic blood pressure, DBP: diastolic Blood pressure, MAP: mean arterial pressure, HR: heart rate.

* P value < 0.05. % change = 100*((LBNP value – baseline value)/baseline value)

Figure 1.

	Variables		LBNP events				% Change		
			Baseline	-30	-45	Sympt(-60)	-30	-45	-60
LT	SBP (mmHg)	Average	123	118	118	110	-4	-4	-10
		SD	17	20	21	25	7	10	15
LT	DBP (mmHg)	Average	75	74	74	70	-1	-1	-7
		SD	9	8	10	12	6	6	13
LT	MAP (mmHg)	Average	91	87	87	83	-4	-4	-8
		SD	10	9	11	14	4	5	13
LT	HR (beat/min)	Average	71	75	87	111 *	6	23	58
		SD	11	12	15	19	6	10	20
LT	Finger width (msec)	Average	683	635	558 *	389 *	-6	-18	-42
		SD	73	88	94	116	13	16	20
HT	SBP (mmHg)	Average	122	117	116	117	-4	-5	-5
		SD	12	10	11	15	3	6	7
HT	DBP (mmHg)	Average	79	77	80	77	-2	2	-2
		SD	9	9	12	11	2	11	6
HT	MAP (mmHg)	Average	92	89	92	92	-3	0	0
		SD	10	11	13	13	2	9	9
HT	HR (beat/min)	Average	69	75	80	87	9	16	27
		SD	9	10	9	7	5	5	13
HT	Finger width (msec)	Average	745	697	654	574	-6	-12	-22
		SD	102	131	92	131	15	11	17

