Hemodynamics and finger PPG width changes during lower body negative pressure

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Introduction: The pulse oximeter is a noninvasive, accurate, continuous indicator of arterial oxygen saturation. Photoplethysmographic signals reflect a combination of volume and flow changes in skin microcirculation. The pulse oximeter measures blood flow at the end arteriolar vessels. Traditionally, plethysmographic determinations have been based upon the amplitude of the plethysmographic waveform; however, other components of the waveform may have different sensitivities to vascular resistance. The finger is a more useful and responsive site when compared to the ear pinna when measuring the activity of the sympathetic system (1). The pulse width is more sensitive than other parameters in the PPG waveform in detecting changes in systemic vascular resistance (2). Hemodynamic parameters such as systolic blood pressure (SBP), diastolic Blood pressure (DBP), mean arterial pressure (MAP) and heart rate (HR) are commonly used for the assessment of hypovolemia (3). Lower body negative pressure (LBNP) creates a reversible hypovolemia by sequestrating 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. Each subject was monitored for EKG to determine heart rate (HR), continuous noninvasive arterial pressure (CNAP) to determine SBP, DBP and MAP and pulse oximeter probe for PPG waveform. These parameters were measured during baseline, -30 mmHg, -45 mmHg, -60 mmHg 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, shortness of breath) 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*((LBNP value - baseline value)/baseline value). Unpaired t-test was performed in both groups at -30 mmHg, -45 mmHg and -60 mmHg LBNP for PPG width SBP, DBP, MAP and HR from baseline. Data was reported as mean ± 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. The variability from baseline for finger PPG width, MAP and SBP 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 ~1000mL blood loss (LBNP -45 mmHg), and no changes in blood pressure were detected. On the other hand, the finger PPG width showed significant reduction at -45 mmHg and -60 mmHg LBNP in the LT group while no changes in blood pressure were detected.

Conclusion: the PPG waveform width could be a more reliable tool for early detection of hypovolemia in LT group than SBP, DBP, MAP and HR during progressive LBNP.

References: