Study of Nasal Pulse Oximeter Amplitude During LBNP Induced Hypovolemia

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Background/Introduction:

- In trauma patients, hypotension and tachycardia are late clinical indicators of hypovolemia that are masked by compensatory changes in vascular tone until the point of cardiovascular collapse.[1]
- Early detection of hypovolemia is therefore crucial to increasing survival outcomes in trauma patients.
- The photo plethysmograph (PPG) waveform, while widely used today as a monitor for arterial oxygen saturation, has the potential to be used as a non-invasive clinical tool for monitoring changes in blood volume.[2]
- Using lower body negative pressure (LBNP) simulated hypovolemia, we examined morphological changes in the PPG waveform at the nose and finger sites with changes in stroke volume (SV) and mean arterial pressure (MAP).

Methods:

- With IRB approval, 36 healthy subjects ages 18-40 underwent progressive LBNP (baseline, -15, -30, -45, and -60 mmHg or until the subject became symptomatic).
- Subjects that completed the LBNP protocol without symptoms were designated as high-tolerance (HT) and symptomatic subjects were designated as low-tolerance (LT).
- Subjects were monitored with a 5-lead EKG and continuous non-invasive blood pressure (CNAP). PPG waveforms were monitored using nasal (Xhale) and finger (Nellcor) pulse oximeter probes. Stroke volume (SV) was measured non-invasively using NICOM (Cheetah). All data was digitized and continuously recorded to a laptop using LabChart (ADInstruments).
- LabChart peak analysis was used to measure the average PPG amplitude during each stage of the LBNP protocol.
- Friedman ANOVA and Wilcoxon tests were used to identify changes in hemodynamic and PPG variables, $P < 0.05$ was considered statistically significant.

Results:

- Changes in nasal PPG amplitude demonstrate a strong correlation with changes in stroke volume (SV) in both HT subjects ($r = 0.94$) and LT subjects ($r = 0.91$) while changes in finger PPG amplitude show a lower correlation ($r = 0.73$) and ($r = 0.70$) in HT and LT subjects respectively.
- With progressive LBNP, stroke volume was significantly reduced (i.e. reduction in SV >10%) in both HT and LT subjects with no significant changes in MAP.
- PPG amplitude declined precipitously only at the finger site in both HT and LT subjects at an estimated blood loss of 350cc

- PPG amplitude at both nasal and finger sites declined significantly at an estimated blood loss of 700cc with changes of -17.5% and -42.0% in HT subjects and -28.7% and -37.5% in LT subjects respectively.

Discussion:

- Stroke volume declined with progressive hypovolemia while MAP remained relatively constant demonstrating compensatory changes in vascular tone
- BP and cardiac output were maintained with progressive hypovolemia
- Finger PPG declined before a level of significant hypovolemia was achieved suggesting that changes in finger PPG amplitude are sensitive to early changes in vascular tone but not to central volume loss.[4]
- No significant change in Nasal PPG amplitude was observed in HT subjects until central volume loss was significant
- Changes in nasal PPG amplitude were strongly correlated with changes in stroke volume suggesting that the nasal site is relatively immune to vasoconstriction and more representative of central volume loss.

Conclusion:

- The Nasal PPG waveform may be a more sensitive clinical tool for monitoring early changes in central hypovolemia than the finger PPG waveform

A)	High Tolerance (HT) Group				
	Baseline	15 mmHg	30 mmHg	45 mmHg	60 mmHg
Finger	0	-32.8	-42	-36	-43.3
Nasal	0	-2.2	-17.5	-25.5	-31.2
Stroke volume (SV)	0	-7	-11.9	-20.3	-33.6

B)	Low Tolerance (LT) Group				
	Baseline	15 mmHg	30 mmHg	45 mmHg	60 mmHg
Finger	0	-34.9	-37.5	-27.5	-54
Nasal	0	-14.8	-28.7	-40.5	-43.5
Stroke volume (SV)	0	-1	-14.8	-27.6	-43.7