TRACKING INTRAVASCULAR VOLUME CHANGES IN CHILDREN DURING SPINAL FUSION SURGERY UTILIZING FREQUENCY ANALYSIS OF PLETHYSMOGRAPHIC WAVEFORMS

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Introduction: spinal fusion surgery is often associated with substantial blood loss, requiring fluid resuscitation and blood transfusions. Dynamic noninvasive hemodynamic evaluation has been shown to be more reliable than conventional hemodynamic static pressures such as (CVP) as regard predicting fluid responsiveness.\(^1\,^2\) It has been reported that these dynamic indices of preload are not able to predict fluid responsiveness in children as a result of high vascular compliance in children.\(^3\,^4\) These dynamic parameters were generated by utilizing time domain analysis of PPG and arterial waveforms [such as (ΔPOP, PVI) (pulse pressure variability) (PPV)] \(^5\).

The present study was undertaken to explore the impact of changes in intravascular volume status in spinal fusion surgery on PPG (being a volume signal may be less impacted by high vascular compliance in children) and to utilizing frequency domain analysis technique which is less prone to artifact or motion interference.

Methods: With IRB approval, we studied 19 children undergoing spinal fusion were studied. EKG, blood pressure, invasive arterial pressure, finger pulse oximeter (finger PPG) and airway pressure were recorded at 100 Hz with a data acquisition system (Collect 5/S, GE) and analyzed using frequency analysis (spectrum, 8K, Hamming. Amplitude density) with LabChart 7, (ADInstruments). Low pass and high pass filter were applied to the arterial waveforms and PPG waveforms (figure 1-A, B). With the use of frequency analysis, the amplitude density (AD) of PPG and arterial pressure DC and AC at the respiratory frequency was measured together with AD at the cardiac pulse as shown in figure (1) and then presented as percentage (AD at respiratory frequency /AD at cardiac pulse) as PPG and arterial DC% and AC% modulation (figure 1-C). DC component of PPG (slow baseline modulation induced by ventilation), is related to non pulsatile component and mostly related to venous blood (figure 1-D). Data were analyzed at three different points (2-A-C); 1) baseline, 2) after estimated blood loss of 300 cc (EBL=300 cc) and 3) after fluid resuscitation (either with blood or albumin). Hemodynamic data were recorded. Data are presented as median and Inter-quartile range (IQR) (the third quartile minus the first quartile) figure (2-D). Friedman ANOVA was used to identify changes in PPG and arterial pressure variables. If a significant change was found a second analysis using Wilcoxon signed-rank test was undertaken to clarify where the changes occurred. As a result of multiple comparisons between phases, \(P\) values < 0.017 were considered statistically significant in this context according to Bonferroni correction. All statistical analyses are performed using the MedCalc v12.2.1, software.

Running title; LBNP, PPG waveform analysis
**Results:** There were 19 patients in the age of 10-14 years old, median age is 12 yr old and median weight is 40 kg. In comparison to the baseline, the 300 cc blood loss phase was associated with significant increase in median PPG DC%, AC % modulations. The percent changes in median PPG parameters from baseline were more significant (> 200%) than the magnitude of change in the arterial DC% and AC% modulations (20%) as shown in figure (2-D&E). While during fluid resuscitation phase only PPG DC % and AC% modulations reached a statistically significant level. Hemodynamic data showed no significant changes from baseline. In comparison to the bleeding phase, the fluid resuscitation phase was associated with significant reductions in the PPG DC% and AC% modulations (> 50% reduction). Arterial DC% and AC% modulation showed no significant changes during bleeding and fluid resuscitation phases in comparison to baseline.

**Discussion:** Hypovolemia remains a common clinical challenge for children undergoing spine surgery. It has been shown that the high arterial compliance of children may weaken and offset the respiratory variability in the arterial pressure waveforms parameters such as (PPV) ⁴. With the use of frequency analysis instead of the time domain analysis, the PPG waveforms can track changes in intravascular volume before significant changes in hemodynamics. PPG DC% and AC% modulation were more sensitive to volume changes rather than arterial ones and this can be explained by the fact that in children the arterial waveforms are compliant dependent while PPG waveforms are compliant independent. In comparison to the PVI, the PPG DC% and AC % are locked at the respiratory frequency, which makes them less liable to artifact interference, furthermore comparison of respiratory frequency modulation against the pulse pressure modulations enable to normalize these values and to compare between patients. Also during resuscitation phase and in comparison to the bleeding phase; the PPG DC% and AC % were reduced by >50% (2-D), which make these parameters a useful tool to track fluid therapy and resuscitation during spinal fusion surgery.

**Significance:** PPG DC% and AC% modulation during provide a useful noninvasive tool for detecting hypovolemia in children even before hemodynamic data change as well as guide fluid resuscitation in children undergoing spinal fusion surgery.

**References:**
Figure (1): A) Arterial pressure (A-line) waveforms raw data, together with the A-line DC and A-line AC as a result of low and high pass filter. B) PPG waveforms raw data, together with PPG DC and PPG AC as a result of low and high pass filter. C) Frequency analysis of PPG waveforms utilizing frequency analysis. The DC component is measurement of baseline oscillation with respiratory peak while the AC shows the effect of respiration on the amplitude height of PPG waveforms. D) The relation between PPG DC and the peripheral venous pressure (PVP) waveforms.
**Figure (2):** PPG and arterial waveforms during A) baseline, B) after 300 cc blood loss and C) after fluid resuscitation. D) Table shows the summary of 19 subjects, data presented as median (IQR) with % change from baseline as well as changes from blood loss and fluid resuscitation†. Friedman ANOVA; $: P value < 0.001, #: P value =0.006 Wilcoxon test; **: P value <0.0001, *: P value ≤ 0.007 (2–E) PPG and arterial DC% and AC% modulation.