Frequency analysis of plethysmographic and arterial waveforms during spinal fusion surgery; a novel method of assessment of intravascular blood volume

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Introduction

• Spinal fusion surgery is associated with substantial blood loss, requiring fluid resuscitation and frequent blood transfusions.
• Dynamic indices (stroke volume variability (SVV), pulse pressure variability (PPV)) has been shown to be more reliable than static pressures (CVP) as regard predicting fluid responsiveness. 1,2
• It has been reported that dynamic indices of preload are not able to predict fluid responsiveness in children as a result of high vascular compliance in children. 3-5
• The present study explore the impact of changes in intravascular volume status on plethysmographic (PPG) and arterial waveform parameters utilizing frequency domain analysis technique.

Methodology

• With IRB approval, we studied 19 children undergoing spinal fusion surgery. EKG, blood pressure, invasive arterial pressure, finger pulse oximeter (finger PPG) and airway pressure were recorded at 100 Hz with (Collect 5/S, GE) and analyzed using Fourier analysis.
• Low and high pass filter were applied to arterial and PPG waveforms to separate direct current (DC) (slow baseline modulation induced ) and alternate current (AC, amplitude modulation) (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 were measured together with AD at the cardiac pulse.
• Data presented as percentage (AD at respiratory frequency/AD at cardiac pulse) as PPG and arterial DC% and AC% modulation (figure 1-C).
• Three data points were analyzed: (I) baseline, (II) after estimated blood loss of 300 cc and (III) after fluid resuscitation as in (figure 2-A-C).
• Hemodynamic data were recorded. Data are presented as median and inter-quartile range (IQR) figure (2-D). Friedman ANOVA and Wilcoxon signed-rank test were used to identify changes in PPG and arterial pressure variables. P values < 0.017 were considered statistically significant.

Results

• 19 patients with age range of 10-14 years (median 12 yrs) and median weight of 40 kg were studied.
• 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 than the magnitude of change in the arterial DC% and AC% modulations (> 200% vs. 20%) as shown in figure (2-D & E).
• 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).
• There were no significant changes in arterial DC% and AC% modulation during bleeding and fluid resuscitation phases.

Conclusion

Monitoring respiratory induced PPG changes presents a useful tool for detecting hypovolemia and allowing for goal directed fluid management in pediatric population. This will help to provide stable intraoperative hemodynamic parameters thus decrease the impact of hypotension on the spinal cord during spinal fusion surgery. This can be explained by the fact that PPG DC modulation is believed to be a venous phenomenon and it detects early changes in preload.

References