The Value of the Pulse Oximeter in the Prediction of Beach Chair Position Induced Hypotension During Shoulder Surgery

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Background: Beach chair position (BCP) is commonly used in arthroscopic and open shoulder procedures to improve intraarticular visualization and to reduce the potential for intraoperative neurovascular damage[1]. Assuming beach chair position (BCP) under general anesthesia may result in intraoperative hypotension and cerebral hypoperfursion which may result in neurologic injury as well as postoperative cognitive dysfunction [2-4]. It has been shown by several investigators that PPG baseline respiratory modulation has been related to the movement of venous blood and preload [5,6]. Monitoring of arterial blood pressure reflects changes in vascular tone. In this study we investigate the ability PPG waveform modulation induced by incentive spirometry as well as the preoperative hemodynamic variables to predict intraoperative BCP-induced hypotension.

Methods: With IRB approval, forty-two adult patients (aged 53±15 years, BMI 28.2±5.9 Kg/m^2, 42% female, 58% male) undergoing shoulder surgery were monitored pre induction and post BCP with noninvasive blood pressure measurement (NIBP) and finger PPG. Preoperatively the incentive spirometry (IS) was used to induce respiratory variability of PPG waveform. PPG waveforms were analyzed using frequency and time domain analysis; frequency analysis of PPG waveforms utilizing Fast Fourier transform (FFT) resulted in two modulations: 1) respiratory modulation induced by incentive spirometry (known as PPG DC modulation) and 2) cardiac modulation corresponds to cardiac pulse frequency. PPG DC% is the ratio of respiratory and cardiac frequency amplitude densities of PPG % (See ***Figure 1***). Time domain analysis of PPG waveforms (amplitude modulation of PPG waveforms) induced by incentive spirometry (ΔPOP) was calculated. Baseline systolic blood pressure (SBP), mean arterial pressure (MAP), pulse pressure (PP) and heart rate (HR) were also recorded. Intraoperative hypotension for BCP induced hypotension defined by MAP drop >25% from baseline, drop of SBP < 90 mmHg or the warranted use of pressors. The ability of preoperative MAP, SBP, PP, HR, PPG DC%, and ΔPOP to predict intraoperative hypotension was investigated. The area under the receiver operator curves (ROC) were used to measure the discriminative power of a prediction model. Statistical significance was accepted for p value < 0.01.

Results: Among the 42 patients, 31 developed hypotension during intraoperative positioning into BCP (75.6%). The areas under the receiver operator curve (ROC) values for predicting BCP-induced hypotension were: 0.61 for PP (95% CI: 0.45-0.76, p-value = 0.2268), 0.65 for HR (95% CI: 0.49-0.79, p-value = 0.1857), 0.70 for ΔPOP (95% CI: 0.57-0.86, p-value = 0.008), 0.79 for PPG DC% (95% CI: 0.63-0.95, p-value = 0.0006), 0.81 for MAP (95% CI: 0.67-0.94, p-value <0.0001), and 0.81 for SBP (95% CI: 0.70-0.95, p-value <0.0001). A HR >71bpm showed sensitivity and specificity of 61.3% and 72.7% respectively. MAP > 91mmHg showed sensitivity and specificity of 74.2% and 63.6% respectively while SBP > 120 mmHg showed sensitivity and specificity of 87.1% and 54.6% respectively. With the use of incentive spirometry preoperatively, ΔPOP with a threshold >30 showed a sensitivity and specificity of 77.4% and 54.6% respectively, while PPG DC% with a threshold of > 64 showed sensitivity and specificity of 77.4% and 90.9% respectively.

Conclusions: Functional hemodynamics variables (such as pulse pressure variability (PPV) and systolic pressure variability (SPV)) are not predictive of fluid responsiveness in spontaneously breathing patients. In spontaneously breathing patients the utilization of incentive spirometry with its resulting respiratory modulation of PPG waveforms (preload related) and preoperative systolic blood pressure (vascular tone indicator) were helpful in predicting intraoperative BCP hypotension. It is hoped that these observations may help the anesthesia provider in directing the appropriate therapy (fluid, pressors or both) to address BCP-induced hypotension during shoulder surgery.

Key Words: Beach chair hemodynamics, Pulse oximeter waveform analysis, Hypotension, functional hemodynamics

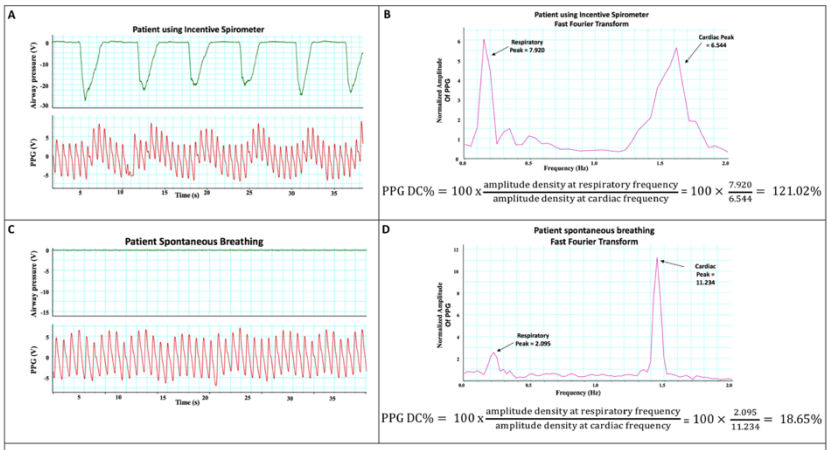

Figure 1: Upper panel, **(A)** during incentive spirometry, airway pressure and finger plethysmograph (PPG). **(B)** Frequency analysis of airway pressure and PPG waveform during incentive spirometry. The amplitude density at respiratory and cardiac frequencies are displayed and corresponding PPG DC% calculation is shown.
Lower panel, **(C)** During spontaneous breathing, airway pressure and finger plethysmograph (PPG), Notice the lacking respiratory modulations of PPG waveform. **(D)** Frequency analysis of airway pressure and PPG waveforms during spontaneous breathing. The amplitude density at respiratory and cardiac frequencies are displayed and corresponding PPG DC% calculation is shown.

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