Cardiac Output Estimation by Multi-Beat Analysis of Arterial Blood Pressure Waveform versus Continuous Pulmonary Artery Thermodilution in Post Cardiac Surgery Intensive Care Unit Patients

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Disclosures available upon request

Introduction:
Cardiac output estimation is a critical component of monitoring critically ill patients after cardiac surgery. We sought to access the correlation between cardiac output estimation using a novel multi-beat analysis of arterial blood pressure waveform versus a traditional continuous pulmonary artery catheter guided thermodilution method.

Methods:
After institutional review board approval, we prospectively enrolled adult cardiac surgical patients recovering post-operatively in the cardiovascular surgical intensive care unit of our tertiary care university hospital. Eligible patients had a functioning pulmonary artery catheter (PAC) and a radial artery line. Continuous thermodilution cardiac output measurements (CO-CTD) obtained via the PAC were retrieved from the electronic medical records (EMR) at a resolution of one measurement every 15 minutes. The arterial blood pressure waveform was fed into the Argos CO monitor (Retia Medical; Valhalla, NY, USA) via a reusable cable connected to the bedside patient monitor. The Argos monitor analyzes the arterial line blood pressure waveform using multi-beat analysis (MBA) and provides CO estimates (CO-MBA) once every 5 seconds. For every available CO-CTD measurement, CO-MBA was averaged over the preceding 30 minutes, in order to obtain paired CO-CTD and CO-MBA measurements.
Correlation between CO-CTD and CO-MBA was computed within subjects, taking repeated observations into account and removing the between subject variability. Agreement between CO-CTD and CO-MBA was assessed via Bland-Altman analysis, accounting for multiple observations within patients. Specifically, the difference between CO-MBA and CO-CTD was modeled as $D_{ij}=\mu+b_i+\epsilon_{ij}$ where D_{ij} is the difference between CO-MBA and CO-CTD, μ is the bias, b_i is the intercept specific to the ith subjects, and ϵ_{ij} is the residual for the jth measurement in the ith subject. The overall variance of D_{ij} is given by the sum of the variances of b_i and ϵ_{ij}.

Results:
Out of the 26 eligible patients, 1 was rejected due to unavailability of continuous thermodilution CO measurements (CO-CTD) from the PAC. One patient was further excluded due to underdamped arterial BP waveforms evident in square wave tests performed throughout the recording. Median length of monitoring where measurement of CO-CTD overlapped with CO-MBA was 14 hours and 15 minutes. A total of 1012 paired measurements across 24 patients was available for final analysis.Mean CO-CTD was 5.12 L/min and mean CO-MBA was 5.54 L/min. Paired observations showed a moderate correlation ($r= 0.62$, $p<0.001$) across a range of values of CO-CTD and CO-MBA. (Figure 1) Bland-Altman plot of the difference between CO-MBA and CO-CTD, plotted against their mean, for all paired measurements showed a mean of differences (bias) of 0.43 L/min +-1.08 L/min, 95% limits of agreement -1.69 to 2.55 L/min, and a percentage error of 39.4 %. (Figure 2)

Conclusion:
Cardiac output measurements using a novel multi-beat analysis of radial artery pressure waveform are moderately correlated with the traditional more-invasive pulmonary artery thermodilution guided cardiac output measurements. Our results agree with a previous validation of the MBA method in 31 post-cardiac surgery patients in the ICU, where a percentage error of 40.7% was reported. Pending larger datasets, intensivists and anesthesiologists have the option of using a relatively non-invasive, easy to use method of cardiac output estimation in post cardiac surgery patients.

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