An analysis of response times for detection of changes in cardiac output in post-operative cardiac surgery patients

Harshavardhan Agashe[1], Jennifer Clarke[1], Lillian M Nosow[2], Lauren E Sands[2], Amit Saha[3], Lynnette Harris[4], Bryan E Marchant[5], Ashish K Khanna[6]

[1]Retia Medical LLC, Valhalla, NY, [2]Wake Forest School of Medicine, Wake Forest Baptist Health, Winston-Salem, NC, [3]Wake Forest School of Medicine, Winston-Salem, NC, [4]Atrium Health Wake Forest Baptist Medical Center, Winston-Salem, NC, [5]Wake Forest Baptist Hospital, Winston Salem, NC, [6]Wake Forest University School of Medicine, Winston-Salem, NC

Introduction

Pulmonary artery catheters (PACs) are used to monitor cardiac output (CO) after cardiac surgery, and are considered the gold standard [1]. However, PACs that use the continuous thermodilution method (CO-CTD)may show a delayed response to changes in patient hemodynamics [2]. Multi-beat analysis (CO-MBA) is a novel method to continuously measure CO from an analysis of the arterial BP waveform. In this analysis we assessed the difference in response times between CO-CTD and CO-MBA.

Methods

This is a post hoc analysis from data collected from adult post-operative cardiac surgery patients in the ICU at the Atrium Health Wake Forest Baptist Medical Center. The primary analysis was aimed at assessing the agreement between CO-CTD and CO-MBA. A standard of care, CO-CTD was measured routinely using a PAC and CO-MBA (Argos Monitor, Retia Medical) was validated against this.

To denote a rapid change in CO, data segments were identified where CO-CTD increased or decreased by greater than 20% over 30 minutes. From the 79 patients' data available, 46 such segments were identified in 37 patients. Within each segment, CO-CTD was incrementally shifted back in time from 0 to 30 minutes, and the correlation coefficient (r) with CO-MBA was computed for each increment. As CO-CTD is shifted back, its alignment with CO-MBA improves until the optimal time shift, after which the correlation starts decreasing with additional time increments, resulting in a typical inverted U shape (example in Fig. 2). The optimal time shift, when the correlation is highest, corresponds to the average difference in response time in CO-CTD, compared to the CO-MBA.

Of the 46 data segments, the inverted U shape was observed in 37 segments. In these, the r value at zero time shift was 0.67 [median, 95% CI 0.15 – 0.91], and at the optimal time shift was 0.88 [0.56 – 0.95] (Fig. 3). The optimal time shift was 12 [4 – 24] minutes.

Results

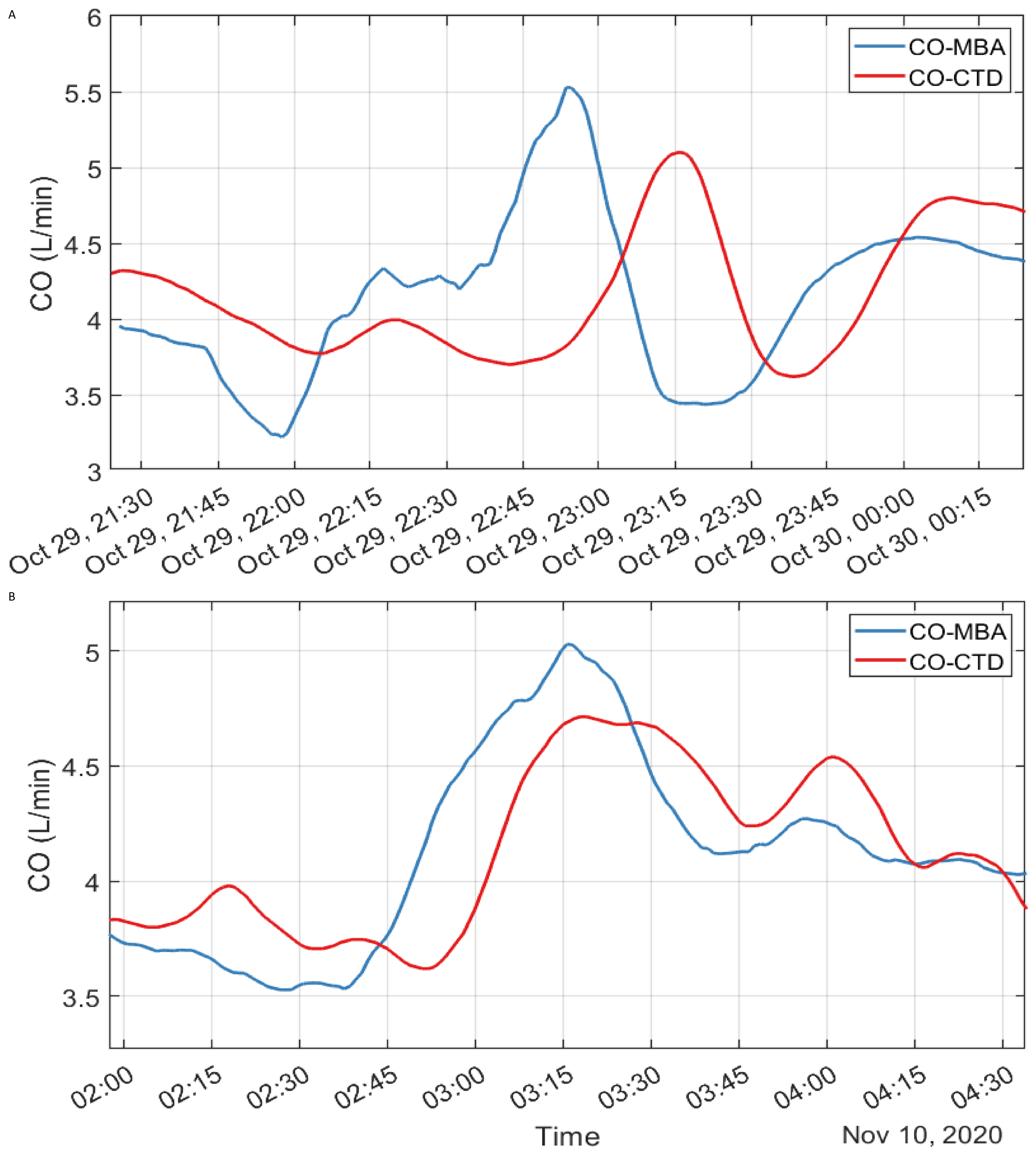

Fig. 1. CO-CTD and CO-MAB show similar but time-shifted patterns of CO changes

Conclusion

The analysis presented here is a novel way to characterize differences in CO measurements timings from two methods. Aranda et al. found that the continuous thermodilution method has a response time of 11 minutes [2], and a manufacturer stated in an FDA adverse event report that the continuous thermodilution averaging time can exceed 20 minutes [3].

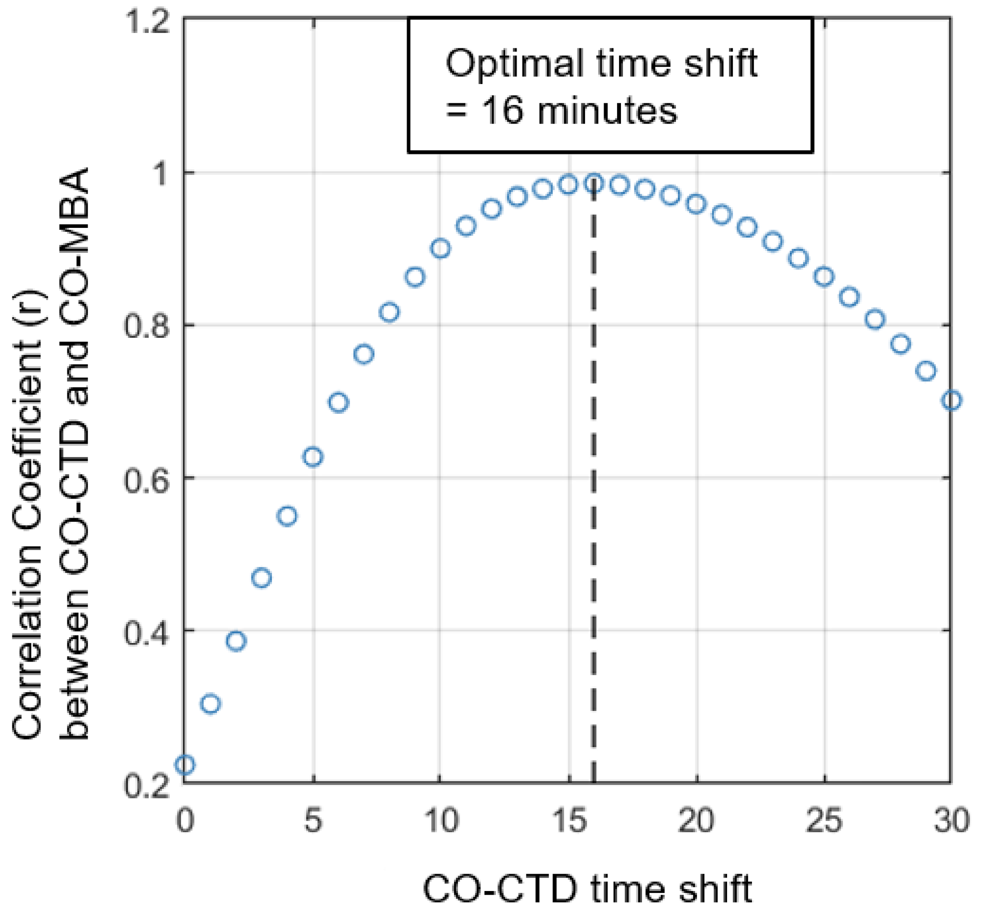

Fig. 2. Correlation coefficient at various time shifts.

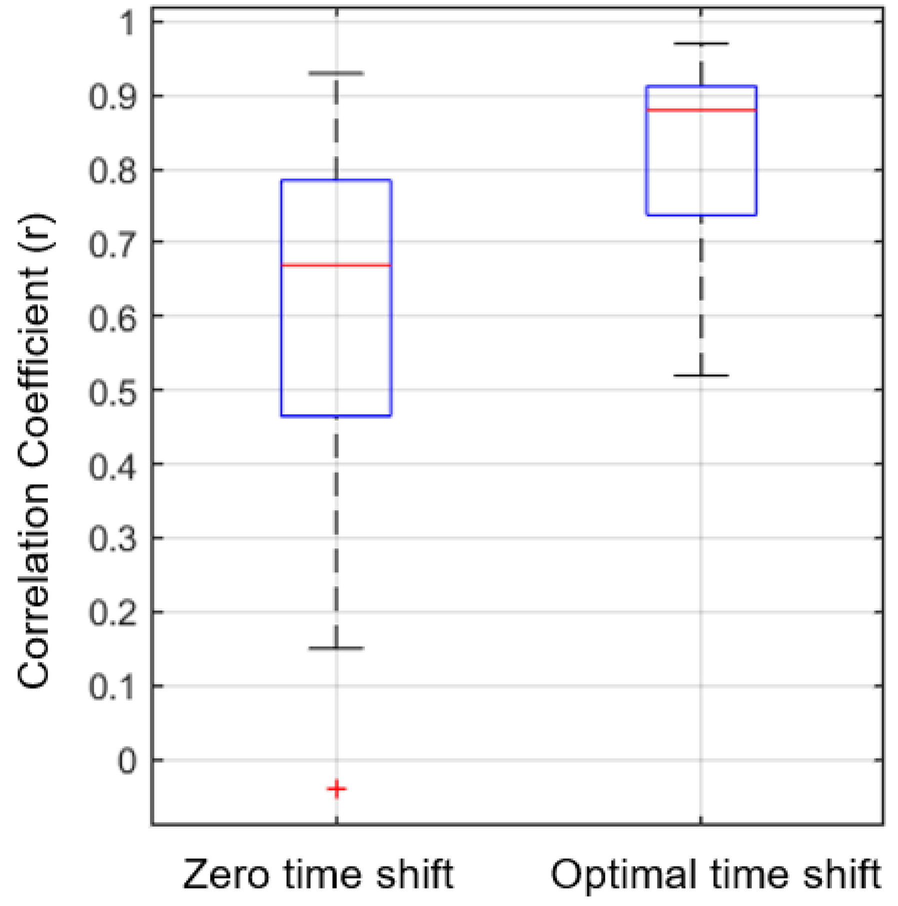

Fig. 3. Improvement in correlation after delay is taken into account.

Pulse-contour analysis methods such as the MBA algorithm have a near real-time response due to its sampling time of 20 s (see discussion in [4]), and show consistent accuracy, including the ability to maintain accuracy during SVR changes [5]. These devices may therefore be considered as a supplement for a PAC or a path to de-escalation of invasive monitoring for post-cardiac surgical patients. Further studies are needed to investigate the clinical relevance of these differences in response times in cardiac output measurement devices.

References

1. X. Watson and M. Cecconi, "Haemodynamic monitoring in the peri-operative period: the past, the present and the future," Anaesthesia, vol. 72, no. S1, pp. 7–15, 2017.
2. M. Aranda, F. G. Mihm, S. Garrett, M. Mihm, and R. G. Pearl, "Continuous Cardiac Output Catheters," Anesthsiology, vol. 89, no. 6, pp. 1592–5, 1998.
3. FDA, "MAUDE Adverse Event Report # 2015691-2011-14924: Edwards Lifesciences, PR Swan-Ganz CCOMBO CCO/SVO2/VIP Thermodilution Catheter with AMC Thromboshield Thermodilution Combo Continuous Cardiac Output Catheter," 2011.
4. M. T. Ganter et al., "Continuous cardiac output measurement by un-calibrated pulse wave analysis and pulmonary artery catheter in patients with septic shock," J. Clin. Monit. Comput., vol. 30, no. 1, pp. 13–22, 2016.
5. G. Greiwe, V. Peters, A. Hapfelmeier, S. Romagnoli, M. Kubik, and B. Saugel, "Cardiac output estimation by multi-beat analysis of the radial arterial blood pressure waveform versus intermittent pulmonary artery thermodilution: a method comparison study in patients treated in the intensive care unit after off-pump coronary artery by," J. Clin. Monit. Comput., vol. 34, no. 4, pp. 643–648, 2019.