

CRASH 2015 – Critical Care Symposium

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Perioperative cardiac output monitoring: how, when, never? – An update for Anesthesiologists

Learning Objectives:

- 1) Physics and Physiology of contemporary cardiac output monitoring devices
- 2) Overview of currently available devices for cardiac output monitoring
- 3) Interdevice differences in cardiac output monitoring
- 4) Cardiac output monitoring for goal directed fluid therapy

Cardiac Output Monitoring¹

Technologies for cardiac output monitoring include the following:

- Thermodilution
- Ultrasound-based techniques
- Bioimpedance and Bioreactance
- Partial rebreathing
- Pulse contour analysis
- Photoplethysmography

Thermodilution is based on the physical principal of conservation of mass. Several assumptions are made to not influence the accuracy of the measurement:

- Measuring a curve over a finite period of time (as opposed to indefinitely)
- Injectate and blood stream are perfectly mixed
- The measured temperature difference is accurate

Thermodilution may be inaccurate in the following clinical scenarios:

- Tricuspid Regurgitation
- Frequent repeated measurements
- Low flow states
- Rapid temperature changes (e.g. post CPB)

- PAC measured CO is right sided only, hence shunt is not accounted for

Ultrasound for hemodynamic monitoring (Doppler)² is a non-invasive and reasonably accurate measurement for CO. It assumes the following:

- Cross-sectional Area stays constant during cardiac cycle
- Measured velocity is the same at all points in the vessel
- For esophageal Doppler
 - Descending thoracic aortic CSA is estimated based on height and weight
 - 30% of flow goes to head vessels and is not accounted for

Thoracic bioimpedance utilizes the concept that electrical resistance of the thorax is dependent on intrathoracic blood volume.

Although minimally invasive, it is less accurate than Doppler or TD. Significant error can be induced for example by pulmonary edema, electrical interference, and incorrect electrode positioning. There are insufficient data to recommend its use.

Partial Rebreathing for determination of CO, relies on the Fick equation for CO₂.

$$CO = V_{CO_2} / (C_{paco_2} - C_{saco_2})$$

VCO₂ = production of CO₂

C_{paco2} = CO₂ concentration in pulmonary artery

C_{saco2} = CO₂ concentration in systemic arterial compartment

Using rebreathing technique, C_{paco2} is solved. C_{saco2} is estimated based on Hgb and partial pressure of CO₂ in arterial blood. This approach assumes a constant shunt fraction and is dependent on minute ventilation and tidal volume. There are limited data to recommend its use.

Devices for pulse contour analysis use calibrated (PICCO, LidCO) vs. non-calibrated (FloTrac) approaches for CO measurement. They all rely on a 2-element Windkessel model:

- Blood entering a vessel during cardiac cycle must also leave the vessel
- During systole vessel expands

- During diastole vessel relaxes

Compliance and instantaneous pressure changes are then measured to determine CO. Calibrated devices are more exact than uncalibrated ones. Overall the accuracy of pulse contour analysis drops during hemodynamic instability (at the time when they are most needed). However, their ability to measure pulse pressure and systolic pressure variation remains intact, thereby providing a reliable way to assess volume responsiveness.

Photoplethysmography uses a finger bladder is inflated to maintain the artery in an “unstretched” state. Finger blood pressure is then the monitored continuously and pulse contour analysis principles are applied to determine CO. Limited data are available to recommend its use.³

Goal directed fluid therapy using the pulmonary artery catheter (PAC) has been found not to confer clinical benefit in critically ill patients.⁴ Whether minimally invasive CO monitoring confers any benefit to patients is unclear. Although many Early Recovery After Surgery (ERAS) programs use goal-directed fluid therapy (GDT), the contribution to successful ERAS concepts is uncertain. For example in septic patients, GDT seems to confer no tangible benefits as compared to usual care in contemporary randomized clinical trials.^{5,6}

References:

1. Thiele RH, Bartels K, Gan TJ. Cardiac output monitoring: a contemporary assessment and review. *Critical care medicine*. Jan 2015;43(1):177-185.
2. Poth JM, Beck DR, Bartels K. Ultrasonography for haemodynamic monitoring. *Best practice & research. Clinical anaesthesiology*. Dec 2014;28(4):337-351.
3. Thiele RH, Bartels K, Gan TJ. Inter-device differences in monitoring for goal-directed fluid therapy. *Canadian journal of anaesthesia = Journal canadien d'anesthesie*. Feb 2015;62(2):169-181.
4. Gattinoni L, Brazzi L, Pelosi P, et al. A trial of goal-oriented hemodynamic therapy in critically ill patients. SvO2 Collaborative Group. *The New England journal of medicine*. Oct 19 1995;333(16):1025-1032.
5. Pro CI, Yealy DM, Kellum JA, et al. A randomized trial of protocol-based care for early septic shock. *The New England journal of medicine*. May 1 2014;370(18):1683-1693.
6. Investigators A, Group ACT, Peake SL, et al. Goal-directed resuscitation for patients with early septic shock. *The New England journal of medicine*. Oct 16 2014;371(16):1496-1506.