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Research Article

End-Tidal Carbon Dioxide as Marker of Cardiac Index after Weaning from Cardiopulmonary Bypass

Vikram Somashekhar Basappanavar*, Sirisha Vadlamani, Shreedhar S Joshi, Mohandas BS, Naveen G Singh and Gaurav Pandey

Cardiac Anaesthesia, Sri Jayadeva Institute of Cardiovascular Sciences and Research, Bangalore, India

***Corresponding Author:** Vikram Somashekhar Basappanavar, Cardiac Anaesthesia, Sri Jayadeva Institute of Cardiovascular Sciences and Research, Bangalore, India.

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Abstract

Objective: To investigate whether end-tidal carbon dioxide tension (ETCO2) could be used as a marker of cardiac index (CI) after weaning from cardiopulmonary bypass (CPB) in patients undergoing cardiac surgeries with CPB.

Design: Prospective, observational clinical study.

Setting: Tertiary cardiac referral teaching hospital.

Participants: Twenty consecutive adult cardiac surgical patients undergoing procedures on CPB.

Interventions: CI was derived with FloTrac-Vigileo device (Edwards Lifescience, Irvine, CA) based on pulse contour analysis connected to femoral artery. The patients were ventilated at 12 - 18 breaths/min with tidal volumes of 7 ml/kg to maintain the $ETCO_2$ between 28 - 32 mm Hg and this. was fixed before going on CPB

Measurements and Main Results: A total of 45 paired data points per patient after weaning off CPB yielded a total of 450 data paired points in 10 patients. The data from calibration group was assessed with regression analysis to yield a relation between observed CI and $ETCO_2$, CI = 0.7527 + 0.09236 ($ETCO_2$). This equation was then applied to $ETCO_2$ values from the validation group patients to derive a predicted CI (pCI). The pCI was assessed for interchangeability with the observed CI (oCI) by applying Bland Altman analysis. The difference of means was 0.5 and 95% confidence interval 0.4572 to 0.6356. Receiver Operating Characteristics – Area under the Curve (ROC-AUC) analysis of predictability of $ETCO_2$ in predicting CI >/= 2 is $ETCO_2$=26 (80% sensitivity and 99.94% specificity).

Conclusions: A $ETCO_2$ greater than 26 mm Hg was invariably associated with a CI more than 2 l/min/m2 under the clinical setting. $ETCO_2$ is a useful index of CI after weaning from CPB.

Keywords: *End-Tidal Carbon Dioxide Tension; Cardiac Index; FloTrac*

Introduction

Assessment of cardiac function after weaning from cardiopulmonary bypass (CPB) is a very important step in cardiac surgery. This requires continuous assessment of cardiac index (CI). Measurement of CI using FloTrac is a widely accepted method [1].

Real-time monitoring of end-tidal carbon dioxide tension (ETCO2) is a mandatory monitor while coming off CPB.

$ETCO_2$ is determined by three factors: carbon dioxide (CO_2) production by cell metabolism, the pulmonary flow (i.e. cardiac output) driving CO_2 from the periphery to the lungs, and the ability of the lung to clear the venous blood of CO_2. Thus, if for a short time interval, two of these three factors are unchanged, changes in $ETCO_2$ might reflect changes of the third factor. Although, there have been many studies showing $ETCO_2$ closely related to cardiac output (CO), during various conditions like predicting volume responsiveness by passive leg raising test [2], extremely low cardiac output [3-6], as a prognostic indicator for survival after cardiopulmonary resuscitation (CPR) [7-16], as an index of coronary perfusion pressure [17], as an index of cerebral perfusion [18], one study has shown that $ETCO_2$ could be used as a predictor of CO following weaning from CPB [19].

We hypothesized that monitoring of $ETCO_2$ could be used to assess CI after weaning from CPB. The present study was planned to assess the correlation of CI and $ETCO_2$, see for interchangeability of CI derived from this relation to observed CI and to analyse the predictive ability of $ETCO_2$.

Methods and Materials

With institutional ethics approval, this study was carried out in twenty consecutive patients aged between eighteen years to sixty five years undergoing cardiac surgical procedures requiring CPB. Ten patients each were enrolled in calibration and validation group. Exclusion criteria were shunt lesions (ASD, VSD), preoperative atrial fibrillation and need for temporary epicardial pacing during weaning from CPB. All patients were free of significant pulmonary disease.

Monitoring included standard electrocardiogram, pulse oximetry, $ETCO_2$, central venous and a femoral arterial catheterization. Anaesthetic management consisted of a balanced technique using propofol (1 - 2 mg/kg) on induction, fentanyl (2 - 5 ug/kg), rocuronium (0.1 mg/kg), and inhaled isoflurane (expired concentration of 0.5%). CI was derived with FloTrac-Vigileo device (Edwards Lifescience, Irvine, CA) based on pulse contour analysis connected to femoral artery. $ETCO_2$ was assessed using infrared technology in expired gas sampled via a sideport system in Draeger Primus ventilator. The patients were ventilated at 12 - 18 breaths/min with tidal volumes of 7 mL/kg to maintain the $ETCO_2$ between 28 - 32 mm Hg and this was fixed before going on CPB.

CPB was conducted according to institutional routine, using intermittent cold cardioplegic arrest. All measurements were obtained when patient temperature was between 36.8 and 37.2˚C. After completion of the surgical procedure and removal of the aortic cross clamp, cardiac rhythm was restored. Based on the pre-CPB heart function, the duration of CPB and aortic cross-clamp and the surgical procedure, vasoactive drugs were administered as needed by anaesthesiologist blinded to the study protocol. The lungs were reinflated and mechanically ventilated with oxygen and isoflurane (0.5% expired concentration). Patients were ventilated with the same ventilator settings which were fixed before going on CPB. ETCO2 and CI were obtained and recorded by a second anaesthesiologist.

Demographic and haemodynamic data were collected. CI and $ETCO_2$ data were collected at fixed interval of one minute from initiation of weaning from CPB till 45 paired data were collected per patient. A total of 45 paired data points per patient yielded a total of 450 data paired points in 10 patients. The data from calibration group was assessed with regression analysis to yield a relation between CI and $ETCO_2$. The relation was applied to the validation $ETCO_2$ values to calculate a predicted CI (pCI). The pCI was then assessed for interchangeability with the observed CI (oCI) by applying Bland Altman analysis. A clinical limit of variance for CI between observed and predicted values of 0.5 was set based on clinical experience. The predictability of $EtCO_2$ to predict a CI >/= 2 was assessed by Receiver Operating Characteristic - Area Under the Curve (ROC-AUC) analysis over 900 data points after combining both the groups.

Results

A total of 20 cases were analysed. 9 Mitral valve replacement (MVR), 9 Aortic valve replacement (AVR), 1 AVR with Coronary Artery Bypass Graft Surgery (CABG) and 1 MVR with CABG cases were enrolled. Demographic data and baseline characteristics are described in table 1. 2 cases were excluded from the study in view of use of pacing to wean off CPB.

Variable	Mean	SD
Age (years)	52	3.9
Height (cms)	152.6	26
Weight (Kg)	52.6	10.5
EuroScore	1.21	1.01
EF (%)	56.6	5.9
Vt (ml)	351.6	47.6
RR (breaths/min)	12.08	1.08
Basal CI (lts/min/BSA)	2.74	0.5
Basal $EtCO_2$	29.21	2.08

Table 1: *Demographic and clinical characteristics.*
Vt: Tidal Volume; EF: Ejection Fraction.

The regression analysis in calibration group yielded the following equation - CI = 0.7527 + 0.09236 ($ETCO_2$) with an intercept of 0.75 (p = 0.0006), slope of 0.092 ($p < 0.0001$) and F-ratio 161.59 ($p < 0.001$) (Figure 1). This equation was applied to the $ETCO_2$ values in validation group patients to derive a predicted CI (pCI). The interchangeability between the pCI and oCI was performed by Bland Altman analysis. The difference of means was 0.5 and 95% confidence interval (95% CI) 0.4572 to 0.6356 (Figure 2). This interchangeability in CI was also depicted by Mountain plot analysis with media -0.6612 (lowest value -3.5841 and highest value 2.0075) (Figure 3). The predictive ability of $ETCO_2$ to predict a CI > 2 as assessed by ROC-AUC yielded an AUC of 0.969 (95% CI - 0.956 to 0.979) with statistical significance ($p < 0.0001$) (Figure 4). The optimal criteria of $ETCO_2$ in predicting CI > 2 is $ETCO_2$=26 (80% sensitivity and 99.94% specificity).

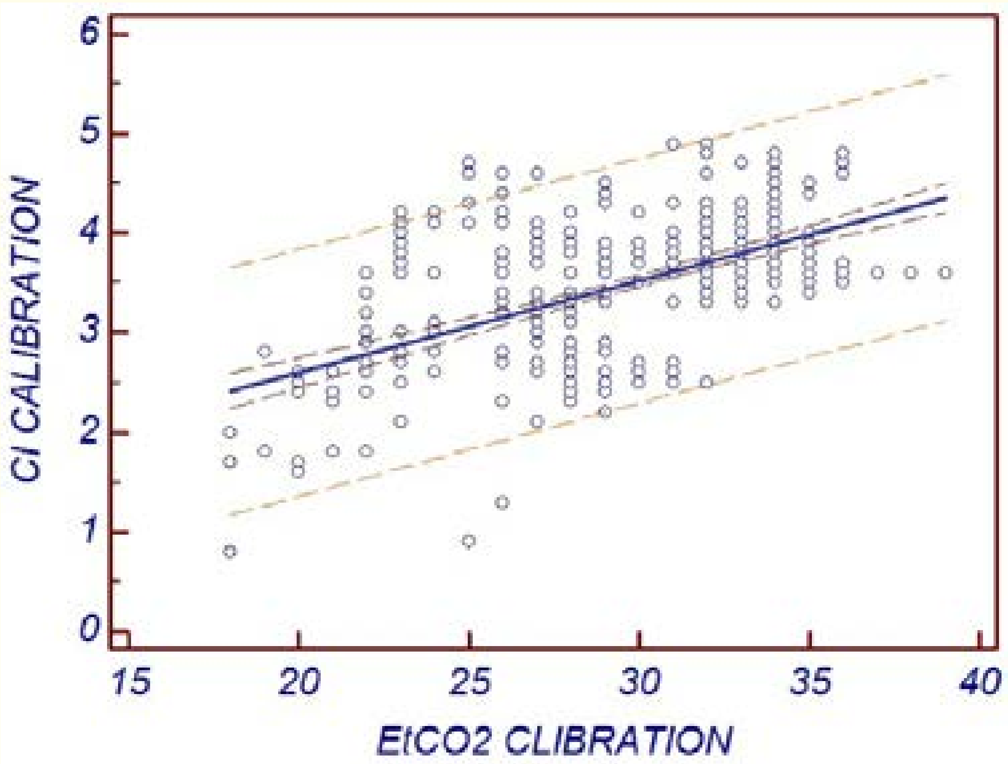

Figure 1: *Correlation co-efficient and relation of CI and ETCO2 in calibration group. CI = 0.7527 + 0.09236 (ETCO2) with an intercept of 0.75 (p = 0.0006), slope of 0.092 (p < 0.0001) and F-ratio 161.59 (p < 0.001).*

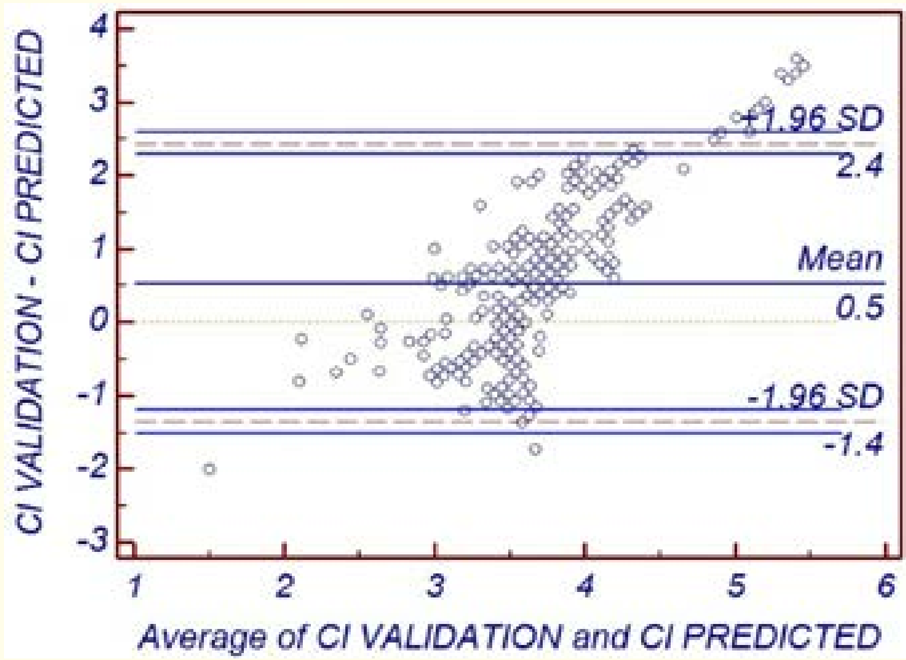

Figure 2: *Bland Altman Analysis of the observed (oCI) versus the predicted (pCI).*

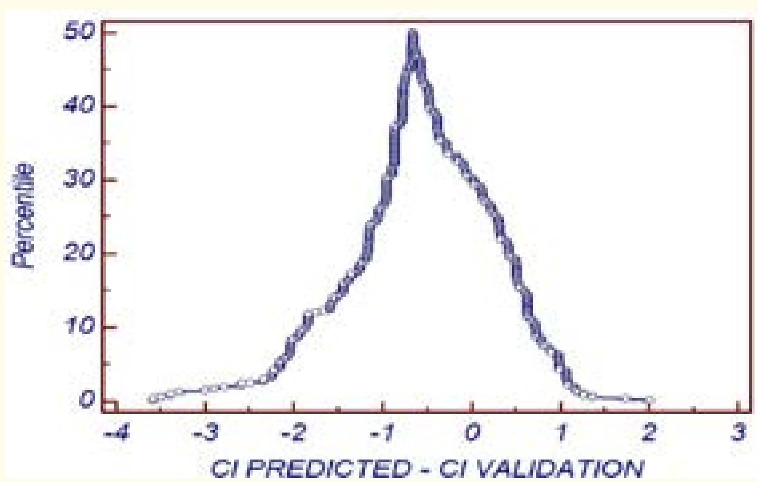

Figure 3: *Mountain plot depiction of the interchangeability of oCI to pCI.*

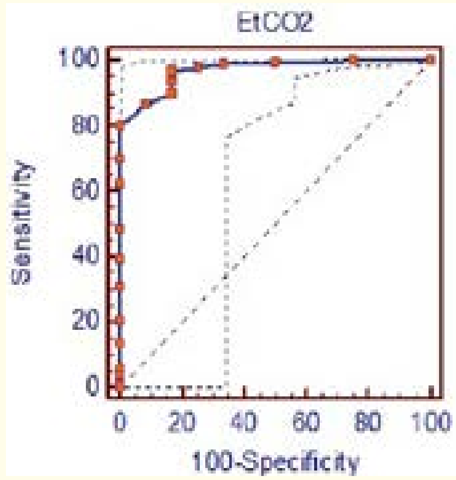

Figure 4: *ROC-AUC analysis of predictability of EtCO2 in predicting CI >/= 2.*

Discussion

We observed a $ETCO_2$ greater than 26 mm Hg was invariably associated with a CI more than 2 $l/min/m^2$ under this clinical setting. The predictive ability of $ETCO_2$ to predict a CI > 2 as assessed by ROC-AUC yielded an AUC of 0.969 (95% CI - 0.956 to 0.979) with statistical significance ($p < 0.0001$).

The intermittent measurement of CI based on the thermodilution technique is widely accepted as the clinical gold standard [20], requires flotation of a pulmonary artery catheter with inherent morbidity. Hence we used FloTrac in our study, which is based on pulse contour, the most popular method [1]. Advantages of FloTrac include the ability to measure CI using an existing arterial catheter and eliminating the need for system calibration.

Andrew., *et al*. [21] demonstrated that monitoring $ETCO_2$ during separation from CPB could be used to assess changes in pulmonary blood flow. They compared $ETCO_2$ to pulmonary artery blood flow (measured by transesophageal Doppler echocardiography) during weaning from CPB. Thermodilution cardiac output was also measured. They observed an $ETCO_2$ value more than 30 mm Hg was invariably associated with a CO more than 4.0 L/min TEE based CI estimation after CPB requires expertise to acquire images, is semi invasive and expensive. These difficulties motivated us to estimate the CI assessment indirectly by $ETCO_2$ values.

While capnography is a direct measurement of ventilation in the lungs, it also indirectly measures metabolism and circulation. $ETCO_2$ allows the global evaluation of three main body functions: metabolism, circulation and ventilation. If two of these parameters are held constant, changes in $ETCO_2$ reflect a variation of the third. Thus, $ETCO_2$ is now widely used as a reliable monitoring device to measure CI. A decrease in $ETCO_2$ reflects decrease in blood flow. Whenever CO_2 delivery from the tissues is low, short-term changes in CO will reflect changes in $ETCO_2$.

Baraka., *et al*. [19] observed regression analysis of $ETCO_2$ at quarter-flow and post-bypass CO showing significant correlation ($r = 0.57$, $p < .001$). Also, regression analysis of $ETCO_2$ after complete weaning from bypass and post-bypass CO showed significant correlation ($r = 0.6$, $p = .002$). The correlation between $ETCO_2$ and CO showed that an $ETCO_2$ >30 mm Hg during partial CPB will always predict an adequate CO following weaning from CPB. In the present study as well, the predicted CI comes in close clinical proximity to observed CI.

And further a $ETCO_2$ > 26 almost always predicts a CI > 2. Such data are useful in situations wherein routine CI monitoring is not available. The haemodynamic variations during the immediate cessation of CPB make this an ideal and robust timing to test the predictive ability of $ETCO_2$ for the CI.

We suggest the use of $ETCO_2$ > 26 as an indirect evidence of clinically sustainable CI in procedures where routine CI monitoring is not available or possible. The validation of this clinical data in non-cardiac surgeries in patients with significant cardiac diseases is advised.

The amount of alveolar and anatomic dead space can change significantly, though ventilation and temperature are maintained. With increasing pulmonary blood flow, the reduction in alveolar dead space would allow more effective alveolar ventilation and elimination of carbon dioxide. This effect may be accentuated with larger changes in blood flow. Monitoring of $ETCO_2$ is easy-to-use and inexpensive method. As it is a routinely used respiratory monitor, it does not require additional cost. Although, additional prospective studies would be useful to support our findings, we recommend that $ETCO_2$ be routinely monitored during separation from CPB to assess cardiovascular function.

Limitations

Since this study was done in cardiac surgical cases, the temperature and vasoactive drugs could not be kept constant. This could be a limitation of our study. More studies are needed to apply these findings in cardiac as well as non-cardiac settings.

Conclusion

The authors conclude that monitoring the changes in $ETCO_2$ be regarded as a valuable non-invasive method to predict CI, in particular when no direct measurement of CI is available.

Conflict of Interest

None

Bibliography

1. Lester AC., *et al*. "Critical Review of the Ability of Continuous Cardiac Output Monitors to Measure Trends in Cardiac Output". *Anesthesia and Analgesia* 111.5 (2010): 1180-1192.

2. Xavier M., *et al*. "End-tidal carbon dioxide is better than arterial pressure for predicting volume responsiveness by the passive leg raising test". *Intensive Care Medicine* 39.1 (2013): 93-100.

3. Jin X., *et al*. "End-tidal carbon dioxide as a noninvasive indicator of cardiac index during circulatory shock". *Journal of Critical Care Medicine* 28.7 (2000): 2415-2419.

4. Ahamed H Idris., *et al*. "End-tidal carbon dioxide during extremely low cardiac output". *Annals of Emergency Medicine* 23.3 (1994): 568-572.

5. Trillo., *et al*. "ETCO2 monitoring during low flow states: clinical aims". *Resuscitation* 27.1 (1994): 1-8.

6. Ornato JP., *et al*. "Relationship between cardiac output and the end-tidal carbon dioxide tension". *Annals of Emergency Medicine* 19.10 (1990): 1104-1106.

7. Sanders AB., *et al*. "End-tidal carbon dioxide monitoring during cardiopulmonary resuscitation. A prognostic indicator for survival". *Journal of the American Medical Association* 262.10 (1989): 1347-1351.

8. Gudipati CV., *et al*. "Expired carbon dioxide: a noninvasive monitor of cardiopulmonary resuscitation". *Circulation* 77.1 (1988): 234-239.

9. Trevino RP., *et al*. "End-tidal CO2 as a guide to successful cardiopulmonary resuscitation: a preliminary report". *Critical Care Medicine* 13.11 (1985): 910-911.

10. Weil MH., *et al*. "Cardiac output and end-tidal carbon dioxide". *Critical Care Medicine* 13.11 (1985): 907-909.

11. White RD and Asplin BR. "Out of hospital quantitative monitoring of end-tidal carbondioxide pressure during CPR". *Annals of Emergency Medicine* 23.1 (1994): 25-30.

12. Callaham M and Barton C. "Prediction of outcome of CPR from end-tidal carbondioxide concentration". *Critical Care Medicine* 18.4 (1990): 358-362.

13. Chase PB., *et al*. "Effects of graded doses of epinephrine on both non invasive and invasive measures of myocardial perfusion and blood flow during cardio-pulmonary resuscitation". *Critical Care Medicine* 21 (1993): 413-419.

14. Callaham M., *et al*. "Effect of epinephrine on the ability of end-tidal carbondioxide readings to predict initial resuscitation from cardiac arrest". *Critical Care Medicine* 20 (1992): 337-343.

15. Ward kR and Yealy DM. "End-tidal carbondioxide monitoring in emergency medicine, part2: Clinical applications". *Academic Emergency Medicine* 5.6 (1998): 637-646.

16. Kalenda Z. "Capnogram as a guide to the efficacy of cardiac massage". *Resuscitation* 6.4 (1978): 259-263.

17. Sanders AB., *et al*. "Expired PCO2 as an index of coronary perfusion pressure". *American Journal of Emergency Medicine* 3.2 (1985): 147-149.

18. Lewis LM., *et al*. "Correlation of end-tidal carbondioxide to cerebral perfusion during CPR". *Annals of Emergency Medicine* 21.9 (1992): 1131-1134.

19. Baraka AS., *et al*. "End-tidal CO2 for prediction of cardiac output following weaning from cardiopulmonary bypass". *Journal of Extra-Corporeal Technology* 36.3 (2004): 255-257.

20. Nishikawa T and Dohi S. "Errors in the measurement of cardiac output by thermodilution". *Canadian Journal of Anesthesia* 40.2 (1993): 142-154.

21. Andrew M., *et al*. "Monitoring End-Tidal Carbon Dioxide During Weaning from Cardiopulmonary Bypass in Patients Without Significant Lung Disease". *Anesthesia and Analgesia* 92.2 (2001): 306-313.

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