International Journal of Research in Medical Sciences
Erkus ME et al. Int J Res Med Sci. 2016 Feb;4(2):369-373
www.msjonline.org
pISSN 2320-6071 | eISSN 2320-6012

DOI: http://dx.doi.org/10.18203/2320-6012.ijrms20160285

Research Article

Comparison of estimated continuous cardiac output with echocardiography in patients with systolic heart failure

Musluhittin E. Erkus[1]*, Ibrahim H. Altiparmak[1], Ahmet Kucuk[2], Funda Yalcin[3], Recep Demirbag[1], Zekeriya Kaya[1]

[1]Department of Cardiology, Harran University Faculty of Medicine, Sanliurfa, Turkey
[2]Department of Anesthesiology, Harran University Faculty of Medicine, Sanliurfa, Turkey
[3]Department of Thorasic Disease, Harran University Faculty of Medicine, Sanliurfa, Turkey

Received: 29 December 2015
Accepted 23 January 2016

***Correspondence:**
Dr. Musluhittin E. Erkus,
E-mail: taha14770@gmail.com

ABSTRACT

Background: Cardiac output (CO) is an important hemodynamic parameter in the management of heart failure. The aim of this study was to compare CO measurements obtained from the bedside monitor specialized for CO measurement, which is known as estimated continuous CO (esCCO), and transthorasic echocardiography (echoCO) in patients with ejection fraction (EF) <40%.
Methods: A total of 49 patients (36 male) with EF <40% were studied in this study. CO was measured using esCCO and transthorasic echocardiography (TTE). Measurements of CO were compared using Bland-Altman statistical method.
Results: Mean ejection fraction was 27.11 ± 7.31%. Measurements of CO using esCCO and echoCO were found to be different (5.44±1.10 L/min vs. 5.08±1.08 L/min, respectively, p=0.004). CO was higher in esCCO compared to TTE. Bland-Altman analysis showed that the bias between esCCO and echoCO was -0.36 L/min [95% CI: -0.60 – (-0.13)], 95% limits of agreement were ranged from -1.77 to 1.05 L/min, and percentage errors of measurements of CO was 13%. A significant positive correlation was found between esCCO and echoCO (r = 0.785, p< 0.001).
Conclusions: esCCO was well correlated with echoCO in patients with low EF. The esCCO may be useful for non-cardiologist such as specialist for anaesthesiology and thorasic disease. Also, it may be used in the patients with HF having poor echocardiographic image quality due to co-morbidities including chronic obstructive pulmonary disease.

Keywords: Cardiac output, Cardiovascular monitoring, Echocardiography, esCCO

INTRODUCTION

Assessment of the cardiac output (CO) is necessary to critically ill patients and requiring follow up hemodynamic monitoring.[1] In order to maintain adequate tissue perfusion, CO should be monitored routinely in patients with decompensate heart failure (HF) or shock.[2] An ideal CO monitoring method should be non-invasive, cost effective, continuous, accurate, safe, reproducible, and have a fast response time.[3,4] There are mainly three methods of CO monitoring; invasive, minimally invasive and non invasive methods. The invasive thermodilution technique is recommended as a reference method for the measurement of CO; however, it has been associated with several significant complications, technical, and reading errors.[5] These negative effects led to the development of new methods of CO monitoring in clinical practice such as estimated continuous cardiac output ($_{es}$CCO).[6-9] However, CO measurement using transthoracic echocardiography (TTE) method ($_{echo}$CO) is the most used technique by a cardiologist. TTE may give inaccurate results in patients with obese and chronic lung disease. On the other hand, it requires expensive

equipment, experience, and time for the measurements of CO.[10]

Compared to $_{echo}$CO, $_{es}$CCO is cheaper and easy to use. In addition, it requires no advanced experience.[11] Previous studies have demonstrated that the $_{es}$CCO has clinically acceptable as much as $_{echo}$CO method in critically ill patients treated in the intensive care unit (ICU) and in patients with performing cardiac surgery.[2,12] However, it is not known whether $_{es}$CCO is a useful tool regarding to cardiovascular monitoring in the patients with systolic heart failure (HFsys). The aim of the study is to compare CO measurements detected using $_{es}$CCO and $_{echo}$CO in the patients with HFsys.

METHODS

Study population

Fifty six adult patients (39 male) with EF <40% were enrolled in this study. Patients with atrial fibrillation, ventricular premature complex, other arrhythmia causing abnormality of the measuring CO, and who having poor echogenicity and taking vasopressor drugs were excluded. CO was simultaneously measured by $_{es}$CCO and TTE. In all subjects, weight and height were measured according to the standard protocols. Then, body surface area (BSA) was computed using DuBois's formula.[13] Cardiac index (CI) was calculated as the ratio of CO to BSA.

Measurement of $_{es}$CCO

$_{es}$CCO were obtained from the hemodynamic bedside monitor (Nihon Kohden, Tokyo, Japan). $_{es}$CCO is determined by pulse wave transit time (PWTT) automatically computed from pulse oximetry waveform and electrocardiogram (ECG) signals. For this procedure, three electrodes were placed on the chest wall (for ECG signals), sensor of the pulse oximeter was put on the right forefinger, and blood pressure cuff was placed on the left brachial area. After inputting of date of birth, sex, weight and height, monitor was calibrated by the heart rate, pulse pressure, and PWTT.[11,14] CO is the production of stroke volume (SV) and heart rate (HR)(CO = SV x HR). The possibility to derive the stroke volume (SV) from pulse pressure (PP) information ($_{es}$CCO = K x (α x PWTT + β) x HR; α, β: experimental constants and K = constant value). The information is described in detail in that paper.[7]

Echocardiographic assessment

The transthoracic echocardiography (TTE) was systematically performed in all subjects according to the standard protocol by an experienced single cardiologist blinded to the study. The intra-observer variability was <4% for all measurements. All measurements were taken with probe of M5S using Vivid 7 (GE, Horten, Norway). LV ejection fraction (EF) was determined by the modified Simpson's method.[15] $_{echo}$CO was calculated using the diameter of the left ventricular outflow tract (LVOT) measured from the inner to inner edge in parasternal long axis view on 2-dimensional echocardiography sampling, the velocity–time integral (VTI) of flow through LVOT calculated as the average of at least three measurement in the apical 5 chamber view by placed cursor using pulsed wave Doppler echocardiography (PW), and heart rate synchronously measured via software of TTE, using that formula: ($_{echo}$CO = LVOT area × VTI_{LVOT} × HR).[6]

Statistics

All data were shown as the mean ± SD. To verify the normal data distributions was performed by one-sample Kolmogorov Smirnov test. The comparison of the two methods was used the paired t test. The bias, precision (SD of bias) and limits of agreement (LOA) (bias ± 1.96 SD) between $_{es}$CCO and $_{echo}$CO was determined by Bland-Altman test.[16] Percentage errors of the acceptable limits of these techniques were calculated using Critchley and Critchley's formula.[17] Bivariate correlation analysis was used in order to find out whether or not there is a relationship between $_{es}$CCO and $_{echo}$CO. Statistical analyses were performed using SPSS version 21 (Chicago, USA). P<0.05 was considered to be significant.

RESULTS

Baseline demographic and clinical variables are shown in Table 1. The data was obtained from 49 patients (36 male, median age=60 years, ranged 33-85 years). Mean ejection fraction was 27.11 ± 7.31%.

Table 1: Baseline demographic and clinical measurements.

Age (years)	60.47 ± 13.53
Systolic blood pressure (mmHg)	114.97 ± 17.37
Diastolic blood pressure (mmHg)	70.82 ± 12.41
Pulse pressure (mmHg)	44.15 ± 14.87
Mean arterial pressure (mmHg)	85.53 ± 12.41
Heart rate (beats/min)	79.29 ± 12.57
Risk factors	
CAD, n (%)	28 (57)
Hypertension, n (%)	13 (26)
Diabetes mellitus, n (%)	6 (12)
Dyslipidemia, n (%)	4 (8)
Smoking, n(%)	14 (28)
Medications	
Acetylsalisilic acide, n (%)	32 (65)
Beta-blocker, n (%)	36 (73)
Statin, n (%)	19 (38)
Diuretic, n (%)	38 (77)
ACEI/ARB, n (%)	35 (71)

Values are expressed mean ± standard deviation and number (percentage).

The measurements obtained from TTE and $_{es}$CCO monitor are shown in Table 2. Measurements of CO using $_{es}$CCO and $_{echo}$CO were found to be different (5.44 ± 1.10 L/min vs. 5.08 ± 1.08 L/min, respectively, p=0.004) in the paired t test. The measurements of CI using both technique were also found to be slightly but significantly different (2.97 ± 0.49 L/min/m^2 vs. 2.80 ± 0.60 L/min/m^2, respectively, p=0.029). In Bland-Altman analysis, the bias between TTE and the monitor was found for CO measurements -0.36 L/min, (95% CI: -0.60 – -0.13) and for CI measurements -0.15 L/min/m^2 (95% CI: (-0.28) - (-0.02)) (Figure 1). In addition, precision, LOA, and percentage error were detected 0.72 L/min, (-1.77; +1.05 L/min), and 13%, respectively. There was a significant positive correlation between $_{es}$CCO and $_{echo}$CO (r = 0.785, p< 0.001) and between $_{es}$CCI and $_{echo}$CI (r=0.773, p< 0.001) (Figure 2). The percentage error of measurement of CI was found to be 10%.

Table 2: Measurements of transthoracic echocardiography and the bedside monitor.

	Mean ± SD	95% Confidence interval	
		Lower	Upper
$_{echo}$CO (L/min)	5.08 ±1.08	4.72	5.43
$_{es}$CCO (L/min)	5.44 ±1.10	5.08	5.80
$_{echo}$CI (L/min/m^2)	2.80 ±0.60	2.59	3.01
$_{es}$CCI (L/min/m^2)	2.97 ±0.49	2.80	3.13
Average of CO (L/min)	5.26 ±1.03	4.92	5.60
Average of CI (L/min/m^2)	2.87 ±0.52	2.69	3.05
$_{es}$SV (ml)	71.64 ± 15.90	66.09	77.19
$_{es}$SVI (ml/m^2)	38.23 ± 7.28	35.69	40.77
Ejection fraction (%)	27.11 ± 7.31	24.70	29.51
LVOT diameter (mm)	21.89 ± 2.19	21.17	22.61
LVOT velocity time integral (cm)	17.58 ± 4.10	16.23	18.93

Values are expressed mean ± standard deviation.
CO, cardiac output; CI, cardiac index; $_{echo}$CO, echocardiographic cardiac output; $_{echo}$CI, echocardiographic cardiac index; $_{es}$CCO, estimated continous cardiac output; $_{es}$CCI, estimated continous cardiac index; $_{es}$SV, estimated stroke volume; $_{es}$SVI, estimated stroke volume index; LVOT, left ventricular outflow tract.

DISCUSSION

CO reflects the amount of blood thrown from the heart to aorta and it also reflects cardiac power.[18] Namely, CO is a global index of circulatory status. CO and its response to therapeutic interventions has been commonly measured in critically ill patients treated in ICU and undergoing surgery in operating room.[2,12,19,20] Although measurement of CO using thermodilution technique (TDCO) is considered the gold standard, several non invasive methods have been compared and found clinically acceptable. In one study, performed by Permpikul C et al, CO measurements were compared using $_{es}$CCO and thermodilution technique in patients with septic shock.[2] They found the bias of 1.2 L/min and LOA from-2.8 to 5.2 L/min. In addition, they declared that $_{es}$CCO could be used as an alternative to pulmonary catheter. In a multicenter study, $_{es}$CCO was also compared with thermodilution technique in patients with and bias was found as 0.13 L/min and the precision of the measurement was detected 1.15 L/min.[14] Also, close correlation between $_{es}$CCO and thermodilution technique was found (r=0.79) and it was expressed that CO measurements determined by both methods were comparable with a small bias and precision. Wacharasint P. et al. studied about clinical validation of $_{es}$CCO by comparing TDCO in patients with undergoing cardiac surgery.[12] They suggested that $_{es}$CCO has an acceptable trend as compared to TDCO.

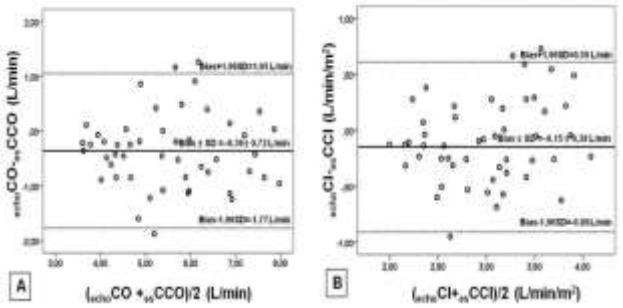

Figure 1: Bland–Altman analysis showing bias and limits of agreements of esCCO and echoCO. A. Cardiac output B. Cardiac index.

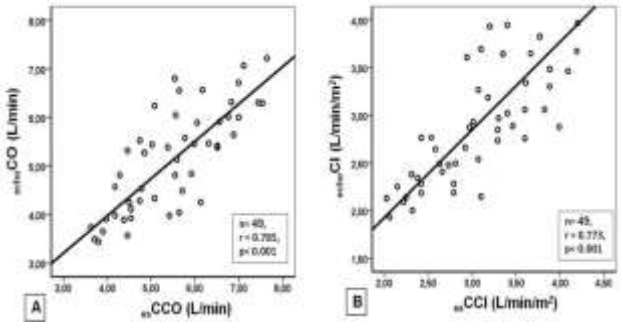

Figure 2: Correlation between esCCO and echoCO. A. Cardiac output B. Cardiac index.

It is indicated that TTE represented a valid alternative to invasive procedures for measuring CO. However, TTE momentarily (not continuously) allows monitoring of CO. In one study, $_{es}$CCO was compared with $_{echo}$CO in patients treated in ICU and a significant correlation was found between $_{es}$CCO and $_{echo}$CO (r=0.61, p<0.001).[21] In addition, bias, precision, and LOA were also found -1.6 L/min, 1.55 L/min, and (-4.7; +1.5 L/min), respectively.

Further, they declared that CO monitorig using $_{es}$CCO was not clinically acceptable with a 49% of percentage error. However, in another study, it was reported that the reproducibility of $_{es}$CCO was satisfactory and it seemed suitable for the purpose of CO monitoring.[22] Besides, they also reported that bias was 1.51 ± 0.84 L/min, and LOA was (-0.14; +3.17) L/min. In present study, we found a significant positive correlation between $_{es}$CCO and $_{echo}$CO ($r = 0.785$, $p< 0.001$). Moreover, in our study, bias, precision, and LOA were found -0.36 L/min, 0.72 L/min, and -2.33; +1.67 L/min, respectively. Difference in the bias for $_{es}$CCO may be due to the different study population. Only, the latter study included the patients having heart failure. On the other hand, the mean of EF of these patients was slightly lower (51% ±15) unlike that in our study (27% ± 7). The percentage error of CO measurements (13%) was smaller than the previous studies.[21,22] This difference of percentage error may be the result of the average of CO being higher than those of the other studies. The percentage error value is considered clinically acceptable if it is <30%, as suggested by Critchley and Critchley.[17] These conditions give rise to thought that $_{es}$CCO can estimate CO with a lower percentage error in setting of HFsys.

The limitation of this study is to be consisted of the population the patients with compensated HFsys.

CONCLUSIONS

It was suggested that the accuracy of $_{es}$CCO is clinically comparable to the thermodilution method. This system is highly invasive due to the requirement of central and pulmonary arterial catheterization, necessary for thermodilution calibration. It has been used as a monitoring tool in high risk surgeries and critical care units. However, it is not unable to evaluate rapid changes in CO induced by a fluid challenge.[23] For CO assessment; we used TTE as the reference method in this study. $_{es}$CCO have some advantages such as noninvasive method, portable and no infection risk. Although $_{es}$CCO in critical ill patients or anesthetized patients is still a matter of debate, we can say that this method can be used in the patients with HFsys. $_{es}$CCO can be used for measurements of CO with a 13% of percentage error in this setting. $_{es}$CCO may be used from non-cardiologists such as specialist for anesthesiology and thoracic disease when CO measurement requires and it can be useful especially in patients with HF, having poor echocardiographic image quality due to co-morbidities including chronic obstructive pulmonary disease. The $_{es}$CCO seems to be simple and suitable method for the measuring CO.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

REFERENCES

1. Marik PE, Baram M. Noninvasive hemodynamic monitoring in the intensive care unit. Crit Care Clin. 2007;23(3):383-400.
2. Permpikul C, Leelayuthachai T. Non-invasive estimated continuous cardiac output (escCO) during severe sepsis and septic shock resuscitation. J Med Assoc Thai. 2014;97(3):184-8.
3. Hofer CK, Ganter MT, Zollinger A. What technique should I use to measure cardiac output? Curr Opin Crit Care. 2007;13(3):308-17.
4. Mehta Y, Arora D. Newer methods of cardiac output monitoring. World J Cardiol. 2014;6(9):1022-9.
5. Maguire S, Rinehart J, Vakharia S, Cannesson M. Technical communication: respiratory variation in pulse pressure and plethysmographic waveforms: intraoperative applicability in a North American academic center. Anesth Analg. 2011;112(1):94-6.
6. Lewis JF, Kuo LC, Nelson JG, Limacher MC, Quinones MA. Pulsed Doppler echocardiographic determination of stroke volume and cardiac output: clinical validation of two new methods using the apical window. Circulation. 1984;70(3):425-31.
7. Ishihara H, Okawa H, Tanabe K, Ishihara H, Okawa H, Tanabe K. A new non-invasive continuous cardiac output trend solely utilizing routine cardiovascular monitors. J Clin Monit Comput. 2004;18(5-6):313-20.
8. Lo HY, Liao SC, Ng CJ, Kuan JT, Chen JC, Chiu TF. Utility of impedance cardiography for dyspneic patients in the ED. Am J Emerg Med. 2007;25(4):437-41.
9. Horster S, Stemmler HJ, Strecker N, Brettner F, Hausmann A, Cnossen J. Cardiac Output Measurements in Septic Patients: Comparing the Accuracy of USCOM to PiCCO. Crit Care Res Pract. 2011. doi: 10.1155/2012/270631. Accessed 30 Nov 2015.
10. Huang SJ, McLean AS. Appreciating the strengths and weaknesses of transthoracic echocardiography in hemodynamic assessments. Cardiol Res Pract 2012. doi: 10.1155/2012/894308. Accessed 30 Nov 2015.
11. Sugo Y, Sakai T, Terao M, Ukawa T, Ochiai R. The comparison of a novel continuous cardiac output monitor based on pulse wave transit time and echo Doppler during exercise. Conf Proc IEEE Eng Med Biol Soc. 2012;2012:236-9.
12. Wacharasint P, Kunakorn P, Pankongsap P, Preechanukul R. Clinical validation of pulse contour and pulse wave transit time-based continuous cardiac output analyses in Thai patients undergoing cardiac surgery. J Med Assoc Thai. 2014;97(1):55-60.
13. DuBois D, DuBois EF. A formula to estimate the approximate surface area if height and weight be known. 1916. Nutrition. 1989;5(5):303-11.

14. Yamada T, Tsutsui M, Sugo Y, Sato T, Akazawa T, Sato N. Multicenter study verifying a method of noninvasive continuous cardiac output measurement using pulse wave transit time: a comparison with intermittent bolus thermodilution cardiac output. Anesth Analg. 2012;115(1):82-7.
15. Lang RM, Bierig M, Devereux RB, Flachskampf FA, Foster E, Pellikka PA. Recommendations for chamber quantification: a report from the American Society of Echocardiography's Guidelines and Standards Committee and the Chamber Quantification Writing Group, developed in conjunction with the European Association of Echocardiography, a branch of the European Society of Cardiology. J Am Soc Echocardiogr. 2005;18(12):1440-63.
16. Bland JM, Altman DG. Agreement between methods of measurement with multiple observations per individual. J Biopharm Stat. 2007;17(4):571-82.
17. Critchley LA, Critchley JA. A meta-analysis of studies using bias and precision statistics to compare cardiac output measurement techniques. J Clin Monit Comput. 1999;15(2):85-91.
18. Cohen-Solal A, Tabet JY, Logeart D, Bourgoin P, Tokmakova M, Dahan M. A non-invasively determined surrogate of cardiac power ('circulatory power') at peak exercise is a powerful prognostic factor in chronic heart failure. Eur Heart J. 2002;23(10):806-14.
19. Dellinger RP, Levy MM, Rhodes A, Annane D, Gerlach H, Opal SM. Surviving sepsis campaign: international guidelines for management of severe sepsis and septic shock: Crit Care Med. 2013;41(2):580-637.
20. Carl M, Alms A, Braun J, Dongas A, Erb J, Goetz A, et al. [Guidelines for intensive care in cardiac surgery patients: haemodynamic monitoring and cardio-circulatory treatment guidelines of the German Society for Thoracic and Cardiovascular Surgery and the German Society of Anaesthesiology and Intensive Care Medicine]. Thorac Cardiovasc Surg. 2007;55(2):130-48.
21. Bataille B, Bertuit M, Mora M, Mazerolles M, Cocquet P, Masson B. Comparison of esCCO and transthoracic echocardiography for non-invasive measurement of cardiac output intensive care. Br J Anaesth. 2012;109(6):879-86.
22. Raissuni Z, Zores F, Henriet O, Dallest S, Roul G. Can we obtain a noninvasive and continuous estimation of cardiac output? Comparison between three noninvasive methods. Int Heart J. 2013;54(6):395-400.
23. Fischer MO, Balaire X, Le Mauff de Kergal C, Boisselier C, Gérard JL, Hanouz JL. The diagnostic accuracy of estimated continuous cardiac output compared with transthoracic echocardiography. Can J Anaesth. 2014;61(1):19-26.

Cite this article as: Erkus ME, Altiparmak IH, Kucuk A, Yalcin F, Demirbag R, Kaya Z. Comparison of estimated continuous cardiac output with echocardiography in patients with systolic heart failure. Int J Res Med Sci 2016;4:369-73.