Validation of Electrical Velocimetry vs. Fick Method and Thermodilution to Determine Cardiac Output in Patients Undergoing Cardiopulmonary Exercise Testing

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Objective

❖Accurate measurement of cardiac output (CO) and stroke volume (SV) is critically important in making diagnoses and guiding patient management.

❖The development of non-invasive techniques to measure CO with comparable accuracy of the gold standard invasive Fick method has been the focus of numerous studies.

❖Electrical velocimetry (EV) is one such technique with promise that has been validated in critically ill patients and pediatric patients at rest. However, whether EV is comparable with the Fick method in a large range of CO and whether it can be used to determine CO during exercise is unknown.

❖The purpose of this study was to compare CO measured with EV to that with the Fick method and thermodilution at rest and during cardiopulmonary exercise testing (CPET).

Methods

❖This study was approved by Partners Human Research Committee (Boston, Massachusetts, USA) and registered at ClinicalTrials.gov (ID: NCT01568619).

❖Patients who were undergoing clinically indicated maximum incremental upright cycle ergometry CPET (5-15 Watt/min continuous ramp after an initial 3 minute period of unloaded exercise, MedGraphics, St. Paul, MN) with pulmonary and radial arterial catheters in place were recruited at Massachusetts General Hospital.

❖Exclusion criteria were severe aortic regurgitation and implanted cardiac pacemaker.

❖CO measured with thermodilution methods (COtherm) were obtained after the insertion of pulmonary artery catheter on the day of test. Cardiac outputs were measured simultaneously with Fick method (COFick) and EV (CO_{EV}) at rest and at one-minute intervals during exercise. COFick was calculated using O2 uptake (VO2) and blood O2 content obtained simultaneously from radial and pulmonary arteries. CO_{EV} was measured using EV with AESCULON (Cardiotronic, La Jolla, California).

❖Agreement of the CO measured with different methods was analyzed by the Bland-Altman method.

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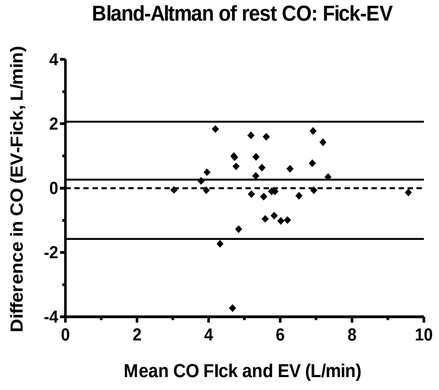
Results

❖Thirty-two patients (age 58.2±14.1 and BMI 29.8±6.3) were enrolled from April 1st to August30th, 2012. Upright cycle ergometry was performed for 7.2±2.0 minutes (mean ±SDev) to 112.7±57.6 watts.

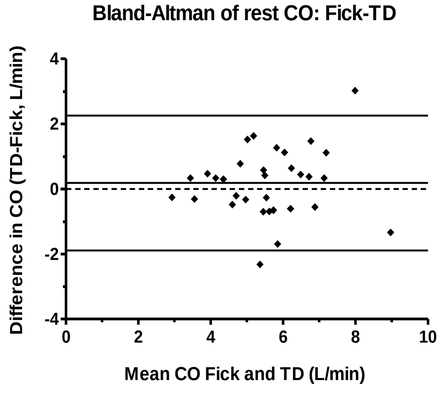
❖At rest, CO_{Fick} and CO_{EV} were not significantly different with a bias of 0.19 L/min and limits of agreement of -2.11 to 2.49 L/min. The agreement of CO_{Fick} and CO_{EV} was similar to that of CO_{Fick} and COtherm (a bias of 0.19 L/min and limits of agreement of -1.93 to 2.31 L/min).

Demographics

Age (yrs)	58.2	±	14.4
Wt (kg)	86.1	±	18.8
Ht(m)	1.7	±	0.1
BMI	29.8	±	6.3
BSA	2.0	±	0.3
male, n (%)	15		(47%)
Dur (mins)	7.2	±	2.0
Watts	112.7	±	57.6



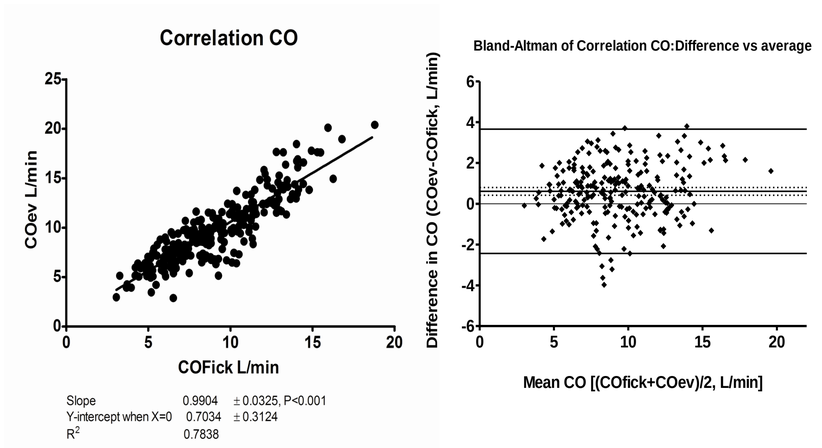
Bia	0.24
SD of bias	0.93
95% Limits of Agreement	
From	-1.62
To	2.10
Percentage error	33.6%



Bia	0.19
SD of bias	1.15
95% Limits of Agreement	
From	-2.11
To	2.49
Percentage error	41.5%

Bia	0.19
SD of bias	1.06
95% Limits of Agreement	
From	-1.93
To	2.31
Percentage error	38.3%

❖During exercise, a total of 342 CO measurements were recorded in the study population and 225 data points were analyzed with 109 data points (32%) excluded due to low signal quality of EV and 8 excluded due to absent blood gas data required for CO_{Fick} calculation. BMI≥30 predicted low signal quality of EV during exercise. A significant correlation between CO_{Fick} and CO_{EV} was shown during exercise (r^2=0.8, p<0.001). Bland-Altman analysis presented a bias of 0.66 L/min and limits of agreement of -2.52 to 3.84 L/min and a percentage error of 31.8%. At maximal exercise, the bias in CO_{EV} and CO_{Fick} was 0.01 L/min and limits of agreement were -3.99 to 4.03 L/min and a percentage error was 31.5%.



CO_{FICK} vs. CO_{EV} during exercise

Conclusions

❖ Our data demonstrates that electrical velocimetry CO measurements provide a simple way to non-invasively measure CO at rest and during exercise. The agreement of EV and Fick at rest is comparable to that of Fick and thermodilution methods. During exercise, there was a strong correlation between CO_{EV} and CO_{Fick} with limits of agreement within the clinically acceptable range. Further studies are needed to optimize EV exercise CO algorithms and to identify confounding variables such as obesity that may limit EV use in certain patient populations. Addition of non-invasive CO measurements to routine non-invasive exercise testing could significantly improve the diagnostic yield of exercise testing.