

Noninvasive Cardiac Index Using Bioimpedance in Comparison to Direct Fick and Thermodilution Methods in Patients with Pulmonary Hypertension

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Purpose

Cardiac Index (CI) measurement is a valuable diagnostic and prognostic tool when treating patients with pulmonary hypertension (PH). Thoracic Electrical Bioimpedance (TEB) provides noninvasive CI measurements that reflect the changes in blood flow through the great vessels during the cardiac cycle. This study provided a three-way evaluation of the accuracy of CI measured using three methods: TEB (CI_{TEB}), direct Fick (CI_{Fick}), and TD (CI_{TD}).

Methods

- 33 ambulatory patients, ages 18-80 years, with echocardiographic evidence of PH underwent right heart catheterization
- Dx: primary pulmonary hypertension (10), chronic thromboembolic d. (22), IPF (1)
- CI_{Fick} was determined from oxygen content of simultaneously obtained arterial and mixed venous blood samples, and from the mean oxygen consumption measurements using a Deltatrac metabolic monitor
- CI_{TEB} measurements were obtained from a BioZ.com™ System (CardioDynamics International Corporation), and CI_{TD} measurements were calculated by a Com II Cardiac Output monitor (Baxter)

Direct Fick Method

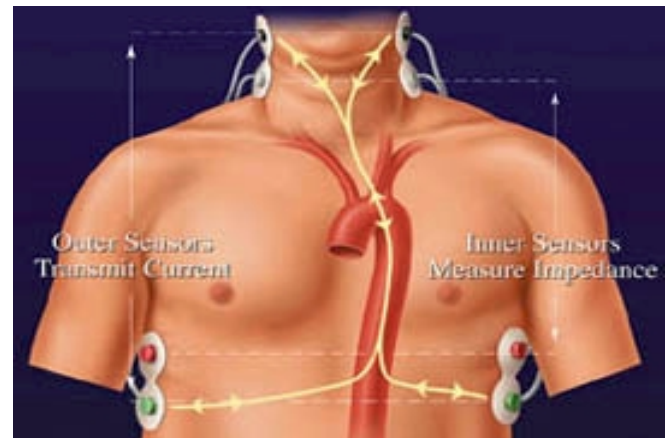
- O_2 consumption (VO_2): Open system indirect calorimetry
Stable FiO_2 , 5 min rest period, RQ between 0.65 to 0.9
- Simultaneous arterial and mixed venous blood sampling
 O_2 content = $1.34 \times Hb \times O_2 \text{ sat} + 0.003 \times pO_2$
- $CO_{Fick} = VO_2 / (CaO_2 - CvO_2)$

Thermodilution Method

- 10 ml room temperature 5% dextrose
- 3 - 5 measurements of CO by independent cardiologist
- $CO_{Fick} = \text{mean of all values}$

Thoracic Electrical Bioimpedance (TEB) Method

Values of CO recorded at one-minute intervals within 10 minutes of CO_{Fick} .



- An alternating current is transmitted through the chest
- The current seeks the path of least resistance: the blood filled aorta
- The BioZ Systems measure the baseline impedance to this current
- With each heartbeat, blood volume & velocity in the aorta change
- The BioZ Systems measure the corresponding change in impedance
- The BioZ Systems use the baseline & changes in impedance to measure & calculate hemodynamic parameters

Advantages of

TEB vs. Thermodilution and Fick Method

- Noninvasive
- Less time consuming
- Minimal skill requirement
- Cost

Results

- Bland and Altman: Three-way comparison for bias & precision
- 'Error' = $\Delta CO / \text{mean CO}$
e.g. $CO_{(TD \text{ vs. Fick})} = \frac{(CO_{TD} - CO_{Fick})}{(CO_{TD} + CO_{Fick})/2}$
- Bias = mean of all errors
- Precision = standard deviation of errors

Figure 1: TEB vs. Direct Fick vs. TD

Table of Results

	Correlation (CO)	Bias (CO)	Bias (CI)	Bias (%)	Precision (CO)	Precision (CI)	Precision (%)
TEB vs. Direct Fick	0.85	-0.24	-0.14	-4.2%	0.84	0.44	19.7%
TD vs. Direct Fick	0.89	0.18	0.09	5.9%	0.80	0.43	19.2%
TEB vs. TD	0.80	-0.42	-0.23	7.0%	1.04	0.55	24.1%

Figure 2: Scatterplot, TEB vs. Direct Fick

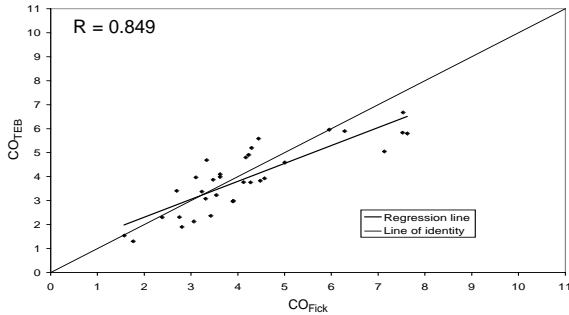


Figure 3: Bland-Altman Analysis, TEB vs. Direct Fick

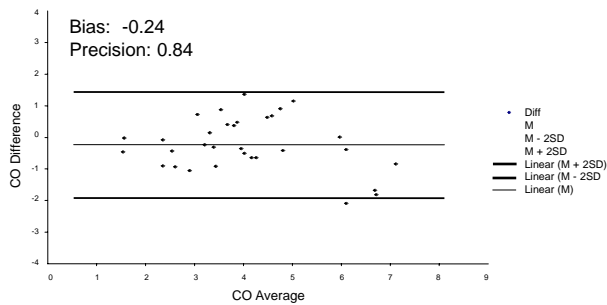


Figure 4: Scatterplot, TEB vs. TD

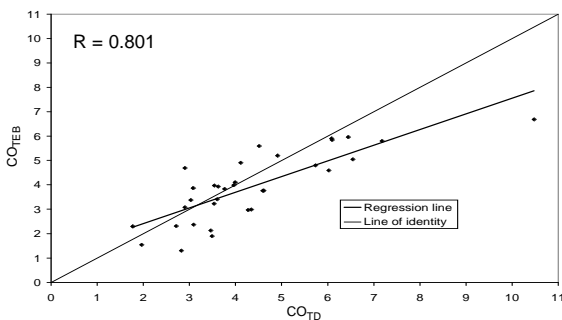


Figure 5: Bland-Altman Analysis, TEB vs. TD

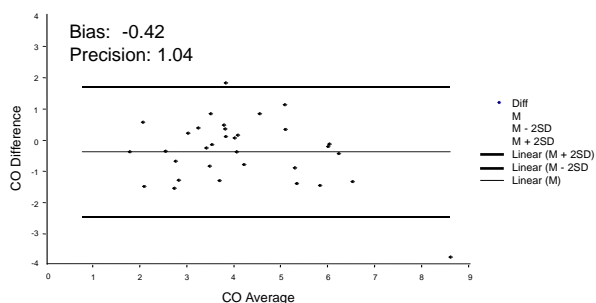


Figure 6: Scatterplot, TD vs. Direct Fick

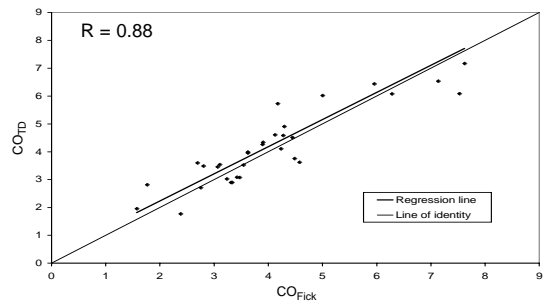
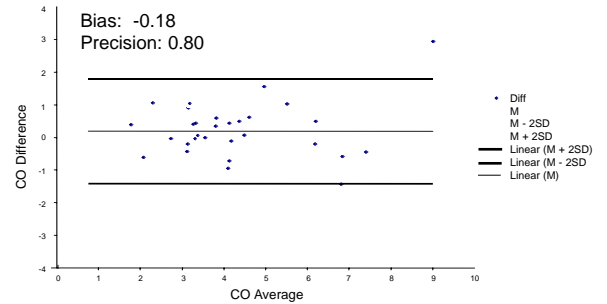


Figure 7: Bland-Altman Analysis, TD vs. Direct Fick



Conclusions

- In spontaneously breathing, non-intubated PH patients, the accuracy of CI_{TEB} was not significantly different to that of CI_{TD} when correlated with CI_{Fick}
- In this study, TEB correlated favorably with the invasive methods (TEB vs. Fick, TEB vs. TD), and almost as well as the invasive methods against themselves (Fick vs. TD)
- The accuracy (precision and bias) of TEB compares favorably to thermodilution method
- TEB is a convenient, less costly alternative that is not associated with the complications of right heart catheterization

Clinical Implications

TEB may be a useful, cost-effective, noninvasive method for determining CI in PH patients, and a potential tool for following responses to therapeutic intervention.