

Reproducibility of Noninvasive Bioimpedance Measurements of Cardiac Function

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Purpose

The purpose of this study was to determine reproducibility in a steady state and to establish normal ranges of selected cardiac parameters, using Thoracic Electrical Bioimpedance (TEB) measurements in patients with known cardiovascular disease.

Sample and Setting

Indices of cardiac function were measured prospectively in a convenience sample of 96 men and women enrolled in an outpatient cardiac rehabilitation program.

Methods

Mean arterial pressure (MAP) was measured every five minutes. Hemodynamic indices were recorded every minute during each session and included: heart rate (HR), stroke volume (SV), cardiac output (CO), velocity index (VI), acceleration index (ACI), systemic vascular resistance (SVR) and thoracic fluid content (TFC).

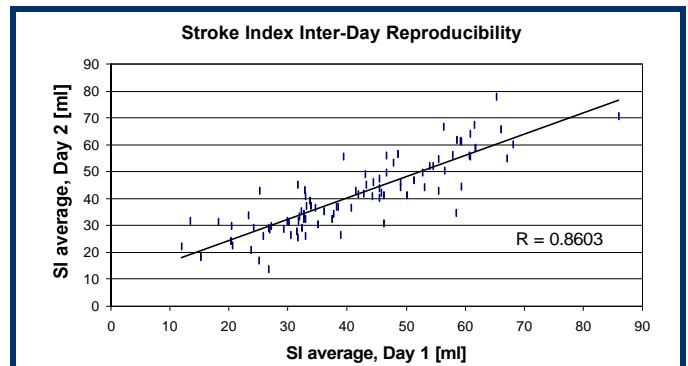
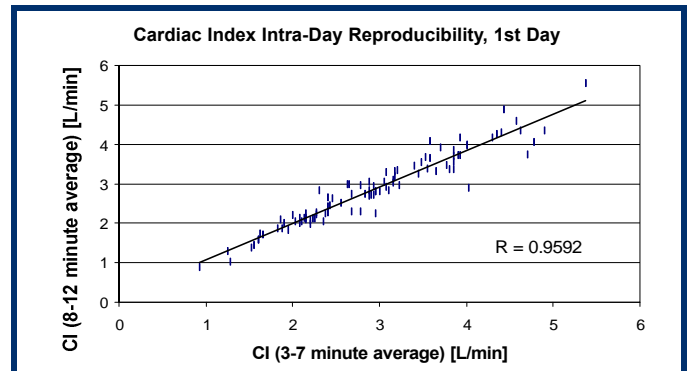
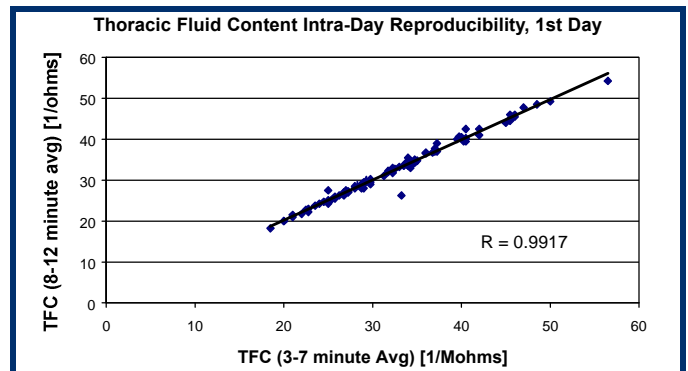
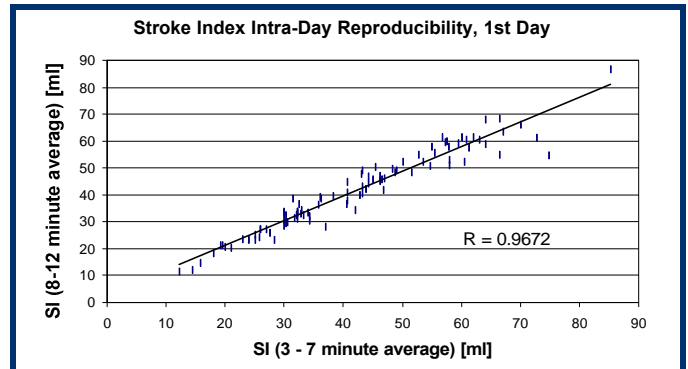
Intra-day reproducibility was established for each patient. The mean values of indices recorded from three to seven minutes and from eight to twelve minutes were compared during each day for intra-day results.

Each patient was then monitored one week later and the sample mean values between Day 1 and Day 2 were compared for inter-day reproducibility.

Instrumentation

Blood pressure measurements were obtained with a Dinamap 1846 SX Vital Signs monitor (Critikon, Tampa, Fla.) and all other cardiac indices were obtained with the BioZ™ system for noninvasive hemodynamic monitoring (CardioDynamics, San Diego, CA).

Results



Results

Parameter	Intra - Day				Inter - Day	
	Day 1		Day 2		Day 1 vs. Day 2	
	mean	+/- 2 SD	mean	+/- 2 SD	95% confidence interval	Variability from mean
HR	71.5	65.9 – 77.1	71.4	65.4 – 77.4	69.87 - 73.13	+/- 2%
MAP	97.1	88.3 – 105.9	96.1	84.1 – 108.1	93.37 - 99.83	+/- 3%
SV	76	61.6 – 90.4	75	61.4 – 88.6	71.49 – 79.51	+/- 5%
SI	42.3	34.3 – 50.3	41.8	34.4 – 49.2	39.89 – 44.31	+/- 5%
CO	5.3	4.3 – 6.3	5.2	4.2 – 6.2	4.91 – 5.49	+/- 6%
CI	2.9	2.3 – 3.5	2.9	2.3 – 3.5	2.74 – 3.06	+/- 6%
ACI	100	60 – 140	90	50 – 130	82 – 118	+/- 9%
VI	46	38 – 54	46	38 – 54	40 - 50	+/- 10%
SVR	1176	910 – 1442	1140	824 – 1456	1073 - 1243	+/- 7%
SVRI	2112	1630 – 2594	2043	1459 – 2627	1921 - 2235	+/- 7%
TFC	33	32 - 34	33	32 - 34	32 - 34	+/- 3%

Intra-Day (Day 1 and Day 2) Mean Cardiac Parameters and Standard Deviations:

This data shows the mean of the measured parameters, and two standard deviations from the mean, as measured within the same day. The deviations indicate the range of values displayed for this patient population.

Inter-Day (Day 1 vs. Day 2) Confidence Interval and Variability:

The confidence interval is used for predictions. 95% of this sample can be predicted to fall within the ranges identified. The percent variability from Day One to Day Two is shown. Cardiac indices obtained with the BioZ system that occur outside of these ranges after therapeutic interventions can be assumed to be due to the intervention in 95% of this sample.

Analysis

The sample of mean values was compared for intra-day and inter-day reproducibility. Strong intra-session correlation between measures of CI, SVRI, and TFC were found, with a 95% range of error determined by agreement limits (SI: $r = 0.99$ and 0.95 , CI: $r = 0.96$ and 0.92 , SVRI: $r = 0.97$ and 0.84 , TFC: $r = 0.99$ and 0.97 ; $p < .001$). High inter-day correlation was also found (SI: $r = 0.86$, CI: $r = 0.79$, SVRI: $r = 0.76$, TFC: $r = 0.80$; $p < .001$).

Conclusion

The patient with cardiopulmonary disease can be reliably monitored for quantifiable hemodynamic measurements with this noninvasive method. Measurements are highly reproducible on same-day determinations and show device sensitivity to normal hemodynamic changes on inter-day measurements. The availability of expected hemodynamic ranges provides a baseline for objective determination of responses to therapeutic interventions.