Reproductibility of cardiac monitoring in men using impedance cardiography during Müeller maneuver

Adrian Aron, MSc, PhD[1, 3], Donald Zedalis, MD[2], William G. Herbert, PhD[1]

1. Department of Human Nutrition, Food and Exercise, Virginia Tech, Blacksburg, VA, USA; 2. Sleep Disorders Network of Southwest Virginia, Christiansburg, VA, USA; 3. Department of Physical Therapy, Radford University, Radford, VA, USA

REZUMAT

Reproductibilitatea monitorizării cardiace la bărbați în timpul manevrei Müeller folosind un cardiograf pe bază de bioimpedanță

Sindromul de apnee/hipopnee obstructivă în somn (SAHOS) este o afecțiune a aparatului respirator întâlnită în timpul somnului, care se caracterizează prin episoade periodice de colaps al căilor respiratorii superioare. SAHOS contribuie la creșterea riscului de aritmii cardiace, boli cardiovasculare și la scăderea sistemului imunitar. Măsurarea funcției cardiace la pacienții care suferă de SAHOS poate aduce informații necesare în alcătuirea unui tratament clinic cât mai eficace și complet. Un procedeu foarte răspândit de testare a funcției cardiace este folosirea bioimpedanței electrice. ***Scop:*** *Determinarea reproductibilității măsurării parametrilor funcționali cardiaci la subiecții care efectuează manevra Müeller.* ***Material și metodă:*** *Au fost testați 15 bărbați sănătoși, de-a lungul a trei zile, în timp ce efectuau un inspir forțat și susținut împotriva unei glote închise (manevra Müeller-MM). Protocolul a inclus efectuarea în fiecare zi a două apnee simulate de câte 30 de secunde (MM) alternate cu cel puțin 3 minute de respirație normală.* ***Rezultate:*** *Modificările debitului cardiac, ale frecvenței cardiace și ale volumului bătaie din timpul celor două MM au fost similare pe parcursul zilelor de testare. Pentru cele trei testări, coeficientul de variație a fost asemănător.* ***Concluzii:*** *Acest modern cardiograf pe bază de bioimpedanță a demonstrat că poate produce rezultate sigure atunci când se măsoară evoluția dinamică a indicilor cardiaci în timpul unui episod de apnee simulată.*

Cuvinte-cheie: *apnee obstructivă în somn, manevra Müeller, cardiograf pe bază de bioimpedanță*

ABSTRACT

Obstructive sleep apnea hypopnea syndrome (OSAHS) is a form of sleep-disordered breathing highlighted by recurrent episodes of upper airway collapse during sleep. OSAHS contributes to an increased risk of cardiac arrhythmias, cardiovascular disease, and altered immune function. Measuring cardiac function in OSAHS patients can provide information that can help delineate clinical treatment efficacy. Cardiac function has been widely tested using electrical bioimpedance. ***Aim:*** *The aim of this study was to determine the reproducibility of cardiac functional parameters in subjects performing Müeller maneuver.* ***Methods:*** *Fifteen apparently healthy males were tested on three different days in a protocol requiring their performance of forced and sustained inspiratory efforts against a closed epiglottis (Müeller maneuver-MM). On each day, the protocol included performance of two simulated apneas of 30 seconds, with at least 3 minutes of normal breathing in between.* ***Results:*** *Changes from a normal breathing baseline for cardiac output, heart rate and stroke volume were comparable during both MM in all three days. The coefficient of variation was similar on all three trials.* ***Conclusions:*** *This new contemporary bioimpedance cardiography device provided reliable measures of dynamic cardiac responses during a simulated apnea event.*

Keywords: *obstructive sleep apnea, Müeller maneuver, bioimpedance cardiograph*

Introduction

Obstructive sleep apnea hypopnea syndrome (OSAHS) is a serious sleep disorder associated with an increased risk in morbidity and mortality, placing a significant burden on society [1]. The reported long-term sequelae associated with this disorder include various cardiovascular diseases such as hypertension, cardiac arrhythmia, myocardial infarction and congestive heart failure [2]. An increased number of research studies is aimed at understanding the acute and chronic effects of OSAHS on different cardiac functions [3]. The most essential measure of cardiac function is cardiac output (CO). Most of the methods that can accurately estimate CO require catheterization and have to be perfomed in well-equipped and expensive laboratories. Some of the new, non-invasive techniques for cardiac measurement involve rebreathing techniques or usage of thoracic electrical bioimpedance (TEB). Most of the TEB devices have been based upon the equations of Kubicek and coworkers [4] which use variables affected by perspiration, subcutaneous adiposity, and low electrical contact. In the present study, data were collected using a new cardiograph device that is supporting its technology on altered equations able to overcome all the previous shortcomings presented by older equipment. The algorithm used does not utilize basal thoracic impedance measurement or the estimation of blood resistivity. Furthermore, the position of the electrodes is not critical for accuracy of the measurements. The PhysioFlow® device has been validated at rest and at exercise [5], during a maximal progressive exercise [6, 7] as well as at rest in emergency room and intensive care unit trauma patients [8]. However, no data were available on using this device in awake individuals undergoing breath-holding maneuvers that simulate apnea events during sleep. This bioimpedance technology can provide the tool for early identification of left ventricular dysfunction in patients with OSAHS that can warrant prompt treatment.

This study evaluated measurement reproducibility for dynamic changes in cardiac output (CO), stroke volume (SV) and heart rate (HR) induced by the Müeller maneuver (MM)

Contact: Adrian Aron, aaron@radford.edu; 101 Elm Avenue, 1st Floor, Rm 114, Carilion Roanoke Community Hospital, Roanoke, VA, 24013, USA

Table 1. Subject characteristics (Mean ± SD)

	Subjects (n = 15)
Age, yr	37.7 ± 5.6
BMI, kg/m^2	22.8 ± 2.1
Neck circumference, cm	38.1 ± 2.1
SBP, mm Hg	117.3 ± 5.6
DBP, mmHg	76.1 ± 7.3

BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure.

Table 2. Coefficients of Variation (CV) for cardiac output, stroke volume and heart rate calculated over three days. Values represent last 5 seconds period of normal breathing before MM and last 5 seconds of breath-holding during MM

	CV (%)			
	First 30 sec MM		Second 30 sec MM	
	Start of MM	End of MM	Start of MM	End of MM
CO (L/min)	10.31	9.22	10.43	10.11
SV (ml/beat)	10.22	12.63	13.95	14.94
HR (beats/min)	9.09	8.72	10.3	9.2

CO, cardiac output; CV, coefficient of variation; HR, heart rate; MM, Müeller maneuver; SV, stroke volume.

in apparently healthy subjects using a new impedance cardiography. The MM requires forced and sustained inspiratory efforts against a closed epiglottis and imposes acute intrathoracic pressure changes similar to that occuring in an obstructive event of sleep apnea. Consistency of dynamic changes in these variables can help design a simple clinically useful test, easily administered to OSAHS patients to assess their cardiac function in an outpatient environment.

Methods

Fifteen apparently healthy, normal weight males were recruited for this study (Table 1). Exclusion criteria consisted of: current cigarette smoking; acute respiratory infections during the previous 6 weeks; diagnosed or medically treated cardiovascular, pulmonary (including asthma), renal, inflammatory or metabolic disorders and blood pressure higher than 130/90 mmHg. Written informed consent was obtained from all subjects and the Virginia Tech institutional review board authorized the study protocol.

Subjects were tested in the supine position, in the same room, on three separate days at ±1 hour interval from the first day. On each day, the protocol included performance of two MM of 30 seconds duration with at least 3 minutes of normal breathing in-between. Previous work confirmed that the MM can closely simulate changes in intrathoracic pressure produced during sleep in subjects with OSAHS [9].

Cardiac variables were collected non-invasively using a TEB device (PhysioFlow PF-05 Lab1, NeuMeDx, Bristol, Pa). The PhysioFlow device and methodology have been described elsewhere [5]. In brief, the bioimpedance method of CO determination uses changes in trans-thoracic impedance during cardiac ejection to calculate SV and electrocardiography (ECG) to determine HR. For measurement of impedance, four electrodes were placed on the subject's base of the neck and supraventricular fossa. In addition, two electrodes were used to measure a single ECG signal (positions V1 and V6).

To determine if the two MM provided stable cardiac responses within a day and between days, 2X3 [(first and second) and (day 1, day 2, day 3)] repeated measures ANOVA was used to evaluate responses for each variable. Coefficient of variation was calculated to show any differences between days. A p value < 0.05 was considered statistically significant. Data were analyzed using SPSS version [17] (Chicago, IL).

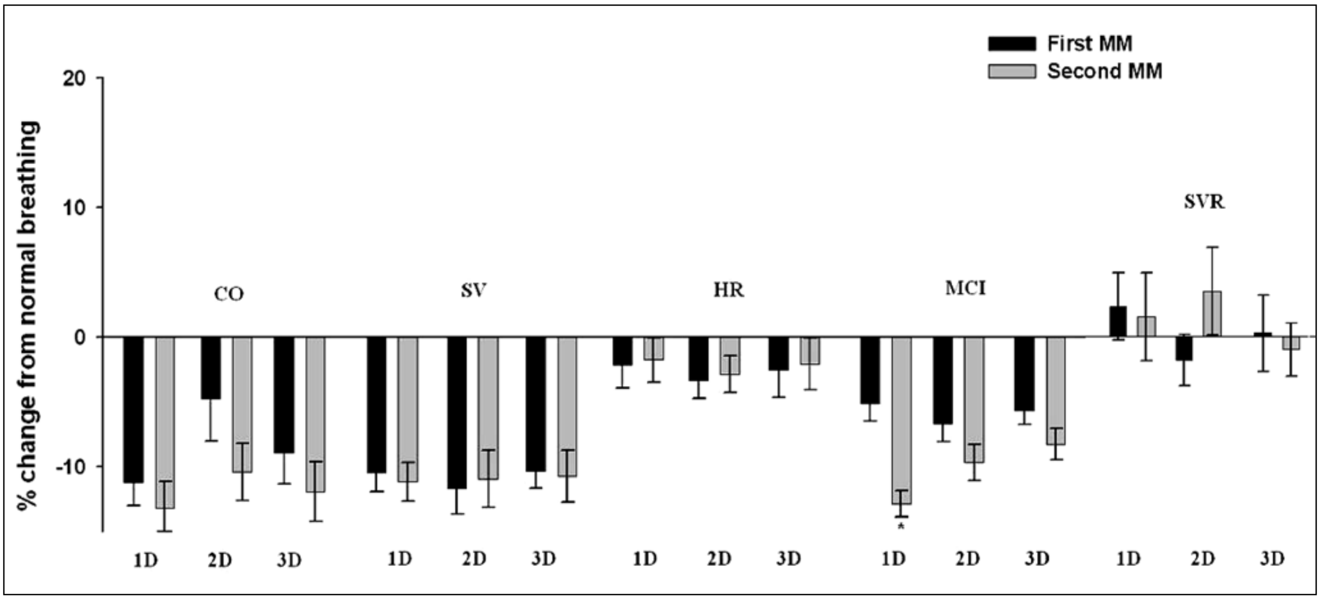
Results

Anthropometric data for the 15 healthy male volunteers are in Table I. All cardiac variables changed similarly within day or between three trials (p = 0.4 to 0.8) (Figure 1). After analyzing changes resulted from 30 sec MM, the coefficient of variation (CV) for the three trails had similar values on the first and second MM for all the cardiac variables, with values ranging from 8.7 – 21.3% (Table II).

Discussion

Trans-thoracic impedance cardiography is a non-invasive cost effective methodology used to estimate SV at rest, during steady state and non-steady state exercise conditions 10. There

Figure 1



are currently more than 200 studies in the literature correlating impedance determinations of CO with some invasive criterion standard measurements. Several comprehensive meta-analyses of this literature have found overall correlations ranging from 0.82 to 0.93 [11, 12]. Reproducibility in stable patients without medical interventions has been demonstrated, with excellent intraday reproducibility of trans-thoracic impedance measurements (r = 0.86) [13].

The lack of more extensive use of this technology comes from the simplistic approach of the equations installed on the devices [14]. These use baseline impedance, which is greatly affected by hydration status, chest wall configuration, distance between electrodes and resistivity of the blood. Conversely, PhysioFlow® technology is using a modified calculation method, basically relying on a Δ change in impedance 5.

This new cardiograph was validated against the direct Fick method. Mean differences between CO values obtained by the direct Fick method and the Physioflow® device were not significant during rest (0.04 l/min) 5, sub-maximal exercise (0.29 l/min) 5, or maximal incremental exercise (0.58 l/min) 6. High correlation values between the two methods were found during rest (r = 0.89) 5, sub-maximal exercise (r = 0.85) 5, and maximal exercise (r = 0.94) 6. Data on the reliability of TEB determinations of CO using the PhysioFlow® device are scarce and there appear to be no data on breath holding testing. Before this technology can be used in clinical setting, any measurement should provide adequate reproducibility. In the present study, the typical error expressed as a CV for CO (9.2-10.4%) and SV (10.2 – 14.9%) were in line with results reported from previous studies. The reliability of "gold standard" methods of cardiac output determination (direct Fick and dye dilution) was around 5–10% and other non-invasive methods for CO measurements had CV ranging from 5 to 20% [15]. Good reproducibility shown by this new cardiograph can provide the basis for usage in a clinical setting to assess occult cardiac dysfunctions that patients with OSAHS are prone to develop.

In summary, we demonstrated that a recent generation cardiograph with advanced signal and noise-cancelling features could easily assess dynamic changes in cardiac function under conditions of stressful respiratory maneuver in apparently healthy males. There were no differences found in any of the cardiac variables across the three trials. A test with this new cardiograph may be useful in prioritizing patients for polysomnography and CPAP therapy, facilitating expedited medical treatment in high-risk patients.

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