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GAVIN PUBLISHERS

Journal of Thrombosis and Circulation

van Campen CMC and Visser FC J Thrombo Cir: JTC -106.

DOI: 10.29011/ JTC -106. 000006

Research Article

Validation of Stroke Volume Measured with Suprasternal Aortic Doppler Imaging: Comparison to Transthoracic Stroke Volume Measurements

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Citation: van Campen CMC, Visser FC (2018) Validation of Stroke Volume Measured with Suprasternal Aortic Doppler Imaging: Comparison to Transthoracic Stroke Volume Measurements. J Thrombo Cir: JTC -106. DOI: 10.29011/ JTC -106. 000006

Received Date: 15 October, 2018; **Accepted Date:** 26 October, 2018; **Published Date:** 2 November, 2018

Abstract

Rationale: During head up, tilt testing measurement of Stroke Volume Index (SVI) is informative on hemodynamics. The transthoracic Doppler approach is difficult during standing. Alternatively, suprasternal Doppler measurements can also provide SVI information. Validation of SVI between the techniques is not available in a large group of subjects in literature.

Objective: Therefore, the aim was to compare SVI with suprasternal aortic Doppler and SVI with transthoracic Doppler echocardiography in CFS/ME patients, prone for orthostatic stress.

Methods and Results: 119 consecutive CFS/ME patients underwent HUT. Suprasternal aortic Doppler time-velocity integrals were acquired for Doppler SVI calculation, together with transthoracic Doppler echocardiographic SVI measurements. Both were obtained in the supine position.

The slope of the relation: SVI Doppler suprasternal aortic VTI imaging vs SVI Doppler transthoracic was close to the line of identity.

Conclusions: This large patient study confirms that for hemodynamic assessment during HUT suprasternal Doppler measurements of SVI can be reliably used instead of the standard transthoracic Doppler measurement of SVI.

Keywords: Aortic VTI Doppler Imaging; Chronic Fatigue Syndrome; Stroke Volume; Suprasternal; Transthoracic

Non-Standard Abbreviations and Acronyms

BP : Blood Pressure

BMI : Body Mass Index

BSA : Body Surface Area

CFS/ME: Chronic Fatigue Syndrome/Myalgic Encephalomyelitis

CI : Cardiac Index

CO : Cardiac Output

CWD : Continuous Wave Doppler

DBP : Diastolic Blood Pressure

HR : Heart Rate

HUT : Head Up Tilt Table Testing

ICC : Intraclass Correlation Coefficient

NMS : Neurally Mediated Syncope

OH : Delayed Orthostatic Hypotension

OI : Orthostatic Intolerance

POTS : Postural Orthostatic Tachycardia Syndrome

PWD : Pulsed Wave Doppler

SBP : Systolic Blood Pressure

SVI : Stroke Volume Index

TEE : Transoesophageal Echocardiography

TTE : Transthoracic Echocardiogram

VTI : Time-Velocity Integral

Introduction

Head Up Tilt Table Testing (HUT) is used as a diagnostic tool for unexplained syncope [1-3] as well as for quantification of hemodynamic changes during orthostatic stress [4-6]. To demonstrate the influence of orthostatic stress on hemodynamics, continuous Heart Rate (HR) and Blood Pressure (BP) measurements during HUT are commonly used. Based on these two measurements predefined conditions as Orthostatic Hypotension (OH), Postural Orthostatic Tachycardia Syndrome (POTS) and Neurally Mediated Syncope (NMS) can be diagnosed [7,8]. For more extensive hemodynamic measurements (Stroke Volume (SV) and Cardiac Output (CO)) can be used. SV and CO can be measured by thermodilution (considered to be the gold standard) [9], but is limited by the invasive nature and therefore less useful during HUT. Other non-invasive techniques for the estimation of SVI and CI are transthoracic bio impedance [4,10], acetylene rebreathing [11], dye dilution [12] and Doppler Echocardiography (transthoracic apical imaging) [13-16]. Transthoracic apical imaging is not practical during HUT, due to the need for lateral positioning of the subjects for acquisition of the images.

As an alternative, the Time-Velocity Integral of the aorta (VTI) using a suprasternal approach [17-19] has been used for stroke volume measurements. However, these studies used a limited number of subjects.

Therefore, the aim of this study was to validate the suprasternal VTI Doppler derived stroke volumes by comparison of the stroke volumes with that of transthoracic Doppler echocardiography derived stroke volumes.

For this purpose, 119 consecutive patients with Chronic Fatigue Syndrome/ Myalgic Encephalomyelitis (CFS/ME), undergoing HUT, were studied. The supine aortic VTI derived stroke volumes (prior to the start of the tilt) were compared with previously obtained stroke volumes by standard transthoracic echocardiograms.

Material and Methods

Patient selection

Between November 2012 and December 2016 119 consecutive CFS/ME patients were studied in whom Orthostatic Intolerance (OI) assessment was part of the work-up. All underwent HUT using Nexfin recording for Heart Rate and Blood Pressure. Stroke Volume Indices (SVI) were calculated, using suprasternal continuous wave Doppler aortic VTI measurements (see below). For validation purposes in these subject's continuous wave Doppler echocardiography derived VTI of the aortic valve was acquired by apical imaging.

The study has been carried out in accordance with Declaration of Helsinki and was approved by the MEC of the Slotervaart hospital, Amsterdam, NL.

Doppler echocardiographic measurements

VTI frames were obtained in the resting supine position. The aortic VTI was measured using a continuous wave Doppler pencil probe connected to a Vivid I machine (GE, Hoevelaken, NL) with the transducer positioned in the suprasternal notch. A maximal Doppler signal was assumed to be the optimal flow alignment. At least 2 frames of 6 seconds were obtained. Echo Doppler recordings were stored digitally.

From a transthoracic echocardiogram the diameter of the left ventricular outflow tract was obtained as well as a VTI using continuous wave Doppler echocardiography of the aortic valve.

Data Analysis

For comparison with the transthoracic echocardiography SV only the VTI frames in the supine position, prior to tilting, were analysed. The time velocity integral was measured off line by manual tracing of at least 6 cardiac cycles, using the GE EchoPac post-processing software. This was done for both transthoracic as well as suprasternal acquired VTI's by one operator (CMCvC). Stroke volumes were calculated from the time–velocity integral of the aortic valve, corrected for the aortic valve as described previously [20,21]. SVI was calculated by the equation: corrected LVOT cross-sectional area times the aortic VTI, divided by the Body Surface Area (BSA; DuBois formula). SVI's of the separate cycles were averaged.

Statistical Analysis

Data were analysed using SPSS version 21 (IBM). All continuous data were tested for normal distribution using the K_S test. Except for disease duration and BMI, all data were normally distributed, data are presented as means ± SD. Disease duration and BMI were presented as median and IQR. Groups were compared using Students T test for unpaired data, within group comparison by Students T test for paired data. Graphs were constructed using Graphpad Prism version 6.00, Graphpad software, La Jola California USA. Comparison of regression lines were performed using the Prism software.

For measurement of intra- and interobserver variation 30 VTI aorta images were studied. The operator CMCvC measured the VTI data at least 3 months apart, being blinded for the first analysis. A second operator (FCV) measured the same VTI data being blinded for the name of the patients on the PC screen. This analysis was performed at least 6 months after the tilt study. The Intra-Class Correlation Coefficient (ICC) for intra and interobserver reliability was calculated with SPSS.

Results

Baseline characteristics of ME/CFS patients and HV are presented in (Table 1).

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Baseline characteristics of patients	
	ME/CFS Patients N=119
Age (yr)	43 ± 12*
Female/Male	100/19
Duration CFS/ME (yr)	12 (6-20)
Length (cm)	172 ± 7
Weight (kg)	72 ± 14
BSA (m^2)	1.84 ± 0.18
BMI (kg/m^2)	24 (21-27)
SBP at rest (mmHg)	137 ± 16
DBP at rest (mmHg)	80 ± 8
Norm BPHR on HUT (n=)	79
OH on HUT (n=)	20
POTS on HUT (n=)	20

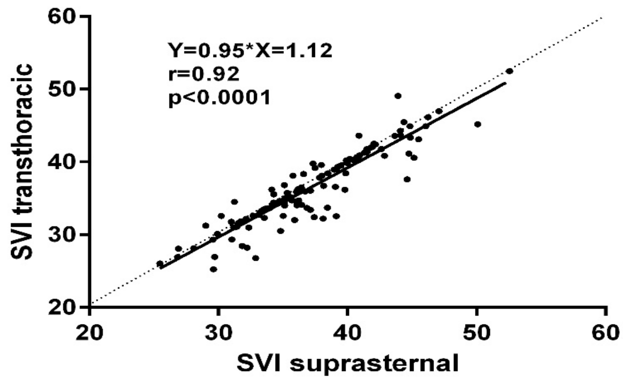
Table 1: BMI = Body Mass Index; BSA = Body Surface Area; BP = Blood Pressure; HUT = Head Up Tilt Table Test; OH = Orthostatic Hypotension (classic and delayed); Normal BPHR = patients with a normal Heart Rate and Blood Pressure response; POTS = Postural Orthostatic Tachycardia Syndrome; yr = years;

79 patients had a normal heart rate and blood pressure response, 20 patients had POTS and 20 a classic or delayed OH. Mean age was 43±12 years, median duration of ME/CFS was 12 (IQR 6-20). Mean Systolic Blood Pressure (SPB) was 137±16 mmHg and mean Diastolic Blood Pressure (DBP) was 80±8 mmHg.

(Table 2) shows the hemodynamic and echocardiographic data of the ME/CFS patients. Heart Rate (HR), the Time Velocity Integral of the aorta (VTI) and Stroke Volume Index (SVI) were derived from both transthoracic echo (TTE) as well as during the supine phase of the Head Up Tilt Test (HUT), using suprasternal Doppler. HR was 73±11 bpm and 71±9 bpm for HUT and TTE respectively. VTI were 24±3 cm for both techniques and SVI was 37±5 ml/m^2 and 36±5 ml/m^2 for suprasternal and transthoracic measurement techniques.

Hemodynamic and echocardiographic characteristics	
	ME/CFS Patients N=119
HR (bpm) supine pre HUT	73 ± 11
HR (bpm) TTE	71 ± 9
VTI (cm) supine pre HUT	24 ± 3
VTI (cm) TTE	24 ± 3
SVI (ml/m^2) supine pre HUT	37 ± 5
SVI (ml/m^2) TTE	36 ± 5

Table 2: HR = Heart Rate; HUT = Head Up Tilt Test (using suprasternal Doppler Aorta VTI measurements) TTE= Transthoracic Echocardiogram; VTI = Time Velocity Integral; SVI = Stroke Volume Index.



SVI = Stroke Volume Index.

Figure 1: Shows the correlation between SVI by suprasternal aortic Doppler echography and by transthoracic apical Doppler echocardiography.

(Figure 1) Shows the correlation between SVI measurements using suprasternal Doppler and transthoracic Doppler measurements. The correlation was highly significant and close to the line of identity with an equation of: $Y=0.95^*X+1.12$; $r=0.92$; $p<0.0001$

(Table 3) Regression analysis of HUT hemodynamic results.

	n	Regression line	R=	p-value
NormHRBP	79	Y = 0,9663*X + 0,4496	0.91	<0.0001
OH	20	Y = 0,9052*X + 3,049	0.96	<0.0001
POTS	20	Y = 0,9567*X + 1,381	0.94	<0.0001

Table 3: N = Number; NormHRBP = Normal Heart Rate and Blood Pressure; HUT = Head Up Tilt Test; OH = Orthostatic Hypotension; POTS =Postural Orthostatic Tachycardia Syndrome.

(Table 3) shows the regression analysis of the three different hemodynamic groups (Figure 2). The slopes of the three regression lines were not significantly different.

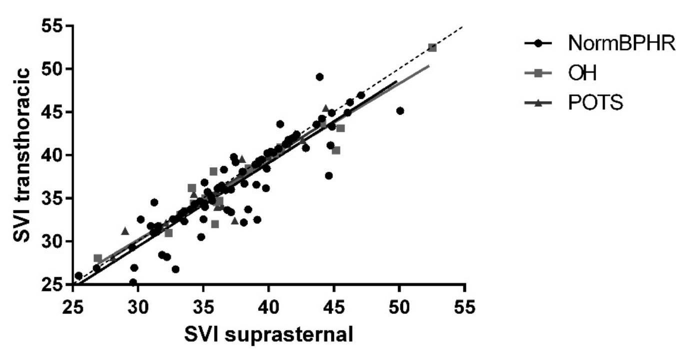


Figure 2: Shows the correlation between SVI by suprasternal aortic Doppler echography and by transthoracic apical Doppler echocardiography of the 3 different HUT hemodynamic outcomes.

HUT= Head Up Tilt Test; SVI= Stroke Volume Index.

The ICC to assess intra-observer variation of the VTI determination was 0.98 and the ICC for inter-observer variation was 0.99.

Discussion

The main finding of this study is that suprasternal Doppler for determination of Stroke Volume Index (SVI) and Cardiac Index (CI) is an accurate technique during HUT giving comparable results as SVI determination with transthoracic aortic Doppler measurements.

One previous study validated the two techniques used in our study in 10 patients with coronary artery disease [22]. In this study a correlation similar to the line of identity, like in our study, was found. They also established that no systematic error was introduced with different observers.

Limited studies are described in literature concerning comparisons of techniques, especially echo Doppler techniques. Bouchard et al. studied 41 patients undergoing cardiac catheterization and compared thermodilution determination of SVI/CI with echo Doppler measurements [18]. In 21 patients with adequate suprasternal and apical images, SVI measurements showed a similar correlation close to the line of identity as in our study.

Spahn et al. studied 25 patients undergoing coronary artery bypass grafting surgery and compared CO results, using two invasive techniques (Fick and thermodilution) and 4 non-invasive measurements, being bio impedance, suprasternal Doppler measurements using Continuous Wave Doppler (CWD) and Pulsed Wave Doppler (PWD), as well as continuous wave Doppler at the aortic valve during Transoesophageal Echocardiography (TEE) [23]. Fick and thermodilution were highly correlated, the echo techniques were only available in 15 (TED and PWD) or 21 patients (CWD). The suprasternal CWD was the most reliable of the 3 echo techniques when compared to thermodilution with r values of 0.84 for CWD, 0.65 for PWD and 0.62 for TEE. For the determination of the aortic valve area, the surgical diameter of the ascending aorta 3-4 cm above the aortic valve was used. Limitations in alignment during transoesophageal echo (TEE) and higher velocities and limited sampling during PWD might be the reason for the poor r values. No comparison of the three echo Doppler techniques was available in this study.

Espersen at al. compared CO measurements using Fick, CO_2 rebreathing and suprasternal pulsed wave Doppler in 11 healthy volunteers [24]. Doppler measurements were accurate in the Fick range of 4.6-8.1 l/min, underestimated CO with higher than 8.1 l/min Fick values and overestimated CO with lower than 4.6 l/min Fick values. No comparison with transthoracic Doppler measurements were available.

Gardin et al. studied intra- interobserver and CO variability with a suprasternal pulsed wave Doppler technique in 10 healthy volunteers [17]. Serial recordings interpreted by the same observer showed reliably alteration in hemodynamics. Only pulsed wave suprasternal Doppler was studied, no comparison was made with continuous wave suprasternal Doppler or transthoracic apical Doppler measurements.

Limitations

The limitations of Doppler SVI determination are that acquisition is time consuming, patient echo window dependent and investigator dependent.

Conclusion

Using suprasternal Doppler imaging to acquire aortic VTI for stroke volume measurements in HUT as the more convenient technique compared to using transthoracic Doppler echocardiography gives reliable results when the two techniques are compared in CFS/ME patients.

Author Contribution Statement

CMC van Campen made a substantial contribution to the concept and design, acquisition of data, analysis and interpretation of data, and drafted the article

FC Visser made a substantial contribution to the concept and design, acquisition of data, analysis and interpretation of data and drafted the article All authors approved the final manuscript

Acknowledgements

We would like to acknowledge all patients who, by participation, made this study possible.

Grants

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Author Conflict of Interest/Disclosures

CMC van Campen: none

FC Visser: none

References

1. Strickberger SA, Benson DW, Biaggioni I, Callans DJ, Cohen MI, et al. (2006) AHA/ACCF Scientific Statement on the evaluation of syncope: from the American Heart Association Councils on Clinical Cardiology, Cardiovascular Nursing, Cardiovascular Disease in the Young, and Stroke, and the Quality of Care and Outcomes Research Interdisciplinary Working Group; and the American College of Cardiology Foundation: in collaboration with the Heart Rhythm Society: endorsed by the American Autonomic Society. Circulation 113: 316-327.
2. Sutton R (2015) The Value of Tilt Testing and Autonomic Nervous System Assessment. Cardiol Clin 33: 357-360.
3. Brignole M,Moya A, de Lange FJ, Deharo Jean-Claude, Elliott PM, et al. (2018) 2018 ESC Guidelines for the diagnosis and management of syncope. Eur Heart J 39: 1883-1948.

4. Mellingsaeter MR, Wyller TB, Ranhoff AH, Bogdanovic N, Wyller VB.(2015) Reduced sympathetic response to head-up tilt in subjects with mild cognitive impairment or mild Alzheimer's dementia. Dement Geriatr Cogn Dis Extra 5: 107-115.

5. Lim E, Chan GS, Dokos S, Ng SC, Latif LA, et al. (2013) A cardiovascular mathematical model of graded head-up tilt. PLoS One 8: e77357.

6. Tahvanainen A, Leskinen M, Koskela J, Ilveskoski E, Nordhausen K, et al. (2009) Ageing and cardiovascular responses to head-up tilt in healthy subjects. Atherosclerosis 207: 445-451.

7. Freeman R, Wieling W, Axelrod FB, Benditt DG, Benarroch E, et al. (2011) Consensus statement on the definition of orthostatic hypotension, neurally mediated syncope and the postural tachycardia syndrome. Auton.Neurosci 161: 46-48.

8. Syncope,Moya A, Sutton R, Ammirati F, Blanc JJ, Brignole M,e t al. (2009) Guidelines for the diagnosis and management of syncope (version 2009). Eur Heart J 30: 2631-2671.

9. Swan HJ, Ganz W, Forrester J, Marcus H, Diamond G, et al. (1970) Catheterization of the heart in man with use of a flow-directed balloon-tipped catheter. N Engl J Med 283: 447-451.

10. Denniston JC, Maher JT, Reeves JT, Cruz JC, Cymerman A, et al. (1976) Measurement of cardiac output by electrical impedance at rest and during exercise. J Appl Physiol 40: 91-95.

11. Triebwasser JHJohnson RL, Burpo RP, Campbell JC,Reardon WC,et al. (1977) Noninvasive determination of cardiac output by a modified acetylene rebreathing procedure utilizing mass spectrometer measurements. Aviat Space Environ Med 48: 203-209.

12. Tuckman J and J Shillingford (1966) Effect of different degrees of tilt on cardiac output, heart rate, and blood pressure in normal man. Br Heart J 28**:** 32-39.

13. Florian JP, Simmons EE, Chon KH, Faes L, Shykoff BE (2013) Cardiovascular and autonomic responses to physiological stressors before and after six hours of water immersion. J Appl Physiol (1985) 115: 1275-1289.

14. Guazzi M, Maltagliati A, Tamborini G, Celeste F, Pepi M, et al.(2000) How the left and right sides of the heart, as well as pulmonary venous drainage, adapt to an increasing degree of head-up tilting in hypertrophic cardiomyopathy: differences from the normal heart. J Am Coll Cardiol 36: 185-193.

15. John JM, Haykowsky M, Brubaker P, Stewart K, Kitzman DW.(2010) Decreased left ventricular distensibility in response to postural change in older patients with heart failure and preserved ejection fraction. Am J Physiol Heart Circ Physiol 299: H883-889.

16. Nwosu EA, Rahko PS, Hanson P, Grogan EW Jr. (1994) Hemodynamic and volumetric response of the normal left ventricle to upright tilt testing. Am Heart J 128: 106-113.

17. Gardin JM, Dabestani A, Matin K, Allfie A, Russell D, et al. (1984) Reproducibility of Doppler aortic blood flow measurements: studies on intraobserver, interobserver and day-to-day variability in normal subjects. Am J Cardiol 54:1092-1098.

18. Bouchard A, Blumlein S, Schiller NB, Schlitt S, Byrd BF 3rd, et al. (1987) Measurement of left ventricular stroke volume using continuous wave Doppler echocardiography of the ascending aorta and M-mode echocardiography of the aortic valve. J Am Coll Cardiol 9: 75-83.

19. Shoemaker JK, O'Leary DD, Hughson RL.(2001) PET(CO(2)) inversely affects MSNA response to orthostatic stress. Am J Physiol Heart Circ Physiol 281: H1040-1046.

20. Kusumoto F, Venet T, Schiller NB, Sebastian A, Foster E. (1995) Measurement of aortic blood flow by Doppler echocardiography: temporal, technician, and reader variability in normal subjects and the application of generalizability theory in clinical research. J Am Soc Echocardiogr 8: 647-53.

21. van Campen CM, Visser FC, de Cock CC, Vos HS, Kamp O, et al. (2006) Comparison of the haemodynamics of different pacing sites in patients undergoing resynchronisation treatment: need for individualisation of lead localisation. Heart 92: 1795-1800.

22. Ihlen H, Endresen K, Myreng Y, Myhre E.(1987) Reproducibility of cardiac stroke volume estimated by Doppler echocardiography. Am J Cardiol 59: 975-978.

23. Spahn DR, Schmid ER,Tornic M,Jenni R, Segesser LV, et al. (1990) Noninvasive versus invasive assessment of cardiac output after cardiac surgery: clinical validation. J Cardiothorac Anesth 4: 46-59.

24. Espersen K, Jensen EW, Rosenborg D, Thomsen JK, Eliasen K, et al. (1995) Comparison of cardiac output measurement techniques: thermodilution, Doppler, CO2-rebreathing and the direct Fick method. Acta Anaesthesiol Scand 39: 245-251.