Myocardial Work Index during Normal Dobutamine Stress Echocardiography

Marina Leitman (✉ marina.leitman@gmail.com)

Yitzhak Shamir Medical Center <https://orcid.org/0000-0002-2908-1858>

Yoni Balboul

Mount Sinai Morningside Hospital

Oleg Burgsdorf

Shamir Medical Center: Yitzhak Shamir Medical Center Assaf Harofeh

Shmuel Fuchs

Shamir Medical Center: Yitzhak Shamir Medical Center Assaf Harofeh

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Abstract

Purpose

Dobutamine stress echocardiography is an alternative method to exercise stress echocardiography for the evaluation of ischemia. Recently, the novel speckle tracking imaging derived parameter, myocardial work index, was suggested for the evaluation of cardiac performance and was evaluated during exercise stress echocardiography. In this study we analyzed the effect of dobutamine on myocardial work index variables during normal dobutamine stress echocardiography.

Methods

Echocardiography examinations of patients with normal dobutamine stress echocardiography were collected and underwent off-line speckle tracking imaging analysis. Myocardial work index parameters were calculated at each dose of dobutamine and compared.

Results

286 patients underwent dobutamine stress echocardiography during the study period. 102 patients were excluded due to pre-existed coronary artery disease or ischemia at dobutamine stress echocardiography. 65 patients were excluded due to suboptimal image quality unsuitable for speckle tracking imaging analysis. The remaining 119 patients with normal results were included. The global work index decreased from 2393.3 to 1864.7 mmHg', $p < 0.0004$. Global constructive work decreased from 2681.7 to 2152.6 mmHg', $p = 0.001$. Global wasted work increased from 78.8 to 128.3%, $p < 0.003$. Global work efficacy decreased from 96.1 to 91.9%, $p < 0.00001$. Global strain increased from -19.6 to -23.7% , $P < 0.00001$. Conclusion. Dobutamine stress echocardiography results in a decrease of all specific myocardial work index parameters even in normal subjects. Only global myocardial strain improved.

Introduction

Dobutamine stress echocardiography (DSE) allows dynamic evaluation of cardiac function during pharmacological stimulation of heart rate, cardiac output, and myocardial oxygen demand. Diagnosis of ischemia is done by visual comparison of left ventricular contraction during dobutamine infusion. In contrast, to exercise stress echocardiography, dobutamine stress echocardiography isn't expected to provide physiological information. Diagnostic accuracy of dobutamine stress echocardiography is determined by sensitivity for detection of coronary artery disease 61–96%, and specificity 70–100% [1]. Visual assessment of contractility is based on the evaluation of wall thickening that's subjective and often completely depends on the experience of the interpreting physician. Recently, few studies evaluated cardiac mechanics during dobutamine stress echocardiography [2, 3] using speckle tracking imaging. The applicability of speckle tracking imaging in dobutamine stress echocardiography is limited by high heart rates. Recently a new speckle tracking imaging parameter, the myocardial work index was introduced [4]. To better understand the physiology of dobutamine stress echocardiography, we applied

speckle tracking imaging, in particular a myocardial work index, in patients with normal dobutamine stress echocardiography.

Materials And Methods

Digital files of the patients that undergo dobutamine stress echocardiography examination were examined. All echocardiography exams were performed using Vivid E95, (General Electric) with a standard transducer of 1.7–4 Hz. The frame rate during echocardiography examinations was greater than or equal to 40 frames per second. Studies with normal results were selected. The clinical characteristics of these patients were obtained from the hospital files. Offline echocardiography analysis included a revision of conventional echocardiography and calculation of myocardial work index variables at baseline and each dose of dobutamine infusion. Myocardial work index variables included: Global work index (GWI), Global constructive work (GCW), Global wasted work (GWW) and Global work efficacy (GWE).

All the patients underwent a standard protocol of dobutamine stress echocardiography with the incremental rise of dobutamine doses every 3 minutes, from 10 mcg/kg/min up to 40 mcg/kg/min. Atropine was delivered at the 20 or 30 mg/kg/min dose of dobutamine as recommended [5], particularly if the heart rate was not increased as expected. ECG and blood pressure measurements were registered every 3 minutes. The target heart rate was determined as 85% of maximal predicted heart rate, $85\% \times (220 - \text{age})$. The study was approved by the local Helsinki committee. Informed consent was not required as data collection was retrospective, anonymous, and speckle tracking imaging analysis didn't influence clinical diagnosis.

Statistical methods. Continuous data were expressed as means $\pm$ standard deviations. The normal distribution for all differences was tested using the Kolmogorov-Smirnov test. A two-tailed, dependent T-test was used. Categorical data were expressed in numbers and percentages. Univariate analysis was performed using Chi-Square/Fisher's exact test (where appropriate) or to identify significant variables ($p < 0.05$).

Results

During 01.2019–06.2019, dobutamine stress echocardiography examinations were performed in 286 patients. 102 patients were excluded due to a prior history of coronary artery disease or inducible ischemia at dobutamine stress echocardiography. 65 patients were excluded due to reduced echocardiography image quality, which wasn't sufficient for adequate speckle tracking. The remaining 119 patients with normal dobutamine stress echocardiography were included in the current study. The mean age was 66, there were 38 males (32%). The main indications for the study were chest pain (53%) and shortness of breath (47%), while the most of patients had risk factors for coronary artery disease [Table 1].

Table 1
Demographic characteristics

Number pts	119
age	66.64 ± 11.32
Male/female	38/81 (32%/68%)
beta blockers*	20 (16.8%)
BMI	30.57 ± 6.77
DM	35 (29%)
HPTN	98 (82%)
Hypercholesterolemia	99(83%)
PVD	32(27%)
Smoker	24(20%)
COPD	15(13%)
CVA	11(9%)
Chest pain	63(53%)
Dyspnea	56(47%)
EF	59.8 ± 1.57%
Atropine	53 (45%)
atropine doses	0.7 ± 0.3
HR	89 ± 4%
*beta blockers were stopped prior to DSE	
BMI - body mass index	
DM – diabetes mellitus	
HPTN - hypertension	
PVD – peripheral vascular disease	
COPD – chronic obstructive pulmonary disease	
CVA-cerebral vascular accident	
HR – heart rate	

The mean ejection fraction (EF) was 59.8%. 53 patients, 45%, received atropine at dobutamine dose 20 or 30 mcg/kg/min, mean atropine dose was 0.7 ± 0.3mg. All the patients reached target heart rate: 13 - at

dobutamine doses of 40 mcg/kg/min, 79 at 30 mcg/kg/min, 27 patients reached target heart rate at dobutamine dose 20 mcg/kg/min. Peak heart rate was $89 \pm 4\%$ of maximal predicted heart rate. Myocardial work index parameters during each stage of dobutamine stress echocardiography and hemodynamic parameters are represented [Table 2, Fig. 1].

Table 2
Myocardial work index parameters during normal dobutamine stress echocardiography

	Baseline	10 mcg/kg/min	20 mcg/kg/min	30 mcg/kg/min	40 mcg/kg/min
SBP, mmHg	149.7 $\pm$ 22.7	156.9 $\pm$ 26.6 <i>p</i> = 0.02	159.9 $\pm$ 28.9 <i>p</i> < 0.003	153.3 $\pm$ 26.8 <i>p</i> = 0.32	140.6 $\pm$ 14.6 <i>p</i> = 0.15
DBP, mmHg	76.3 $\pm$ 12.2	75.6 $\pm$ 14.1 <i>p</i> = 0.7	73.2 $\pm$ 15.9 <i>p</i> = 0.09	71.9 $\pm$ 15.8 <i>p</i> = 0.006	65.6 $\pm$ 16.6 <i>p</i> = 0.007
HR, bpm	71.9 $\pm$ 12.2	107.2 $\pm$ 18.4 <i>p</i> < 0.00001	127.1 $\pm$ 13.8 <i>p</i> < 0.00001	134.8 $\pm$ 11.6 <i>p</i> < 0.00001	133.4 $\pm$ 12.1 <i>p</i> < 0.00001
GS, %	-19.6 $\pm$ 2.4	-22.1 $\pm$ 2.8 <i>p</i> < 0.00001	-23.0 $\pm$ 2.8 <i>p</i> < 0.00001	-23.8 $\pm$ 2.8 <i>p</i> < 0.00001	-23.7 $\pm$ 3.5 <i>p</i> < 0.00001
GWI mmHg'	2393.3 $\pm$ 503.4	2262.0 $\pm$ 572.8 <i>p</i> = 0.06	2189.8 $\pm$ 568.1 <i>p</i> < 0.004	2060.6 $\pm$ 565.2 <i>p</i> = 0.00001	1864.7 $\pm$ 424.4 <i>p</i> < 0.0004
GCW mmHg'	2681.7 $\pm$ 549.6	2581.6 $\pm$ 660.1 <i>p</i> = 0.2	2551.9 $\pm$ 691.6 <i>p</i> = 0.74	2469.9 $\pm$ 717.6 <i>p</i> = 0.02	2152.6 $\pm$ 521.7 <i>p</i> = 0.001
GWW mmHg%	78.8 $\pm$ 56.5	110.9 $\pm$ 53.1 <i>p</i> < 0.00001	131.0 $\pm$ 65.6 <i>p</i> < 0.00001	142.4 $\pm$ 73.7 <i>p</i> < 0.00001	128.3 $\pm$ 45.2 <i>p</i> < 0.003
GWE %	96.1 $\pm$ 3.1	94.2 $\pm$ 2.8 <i>p</i> < 0.00001	93.0 $\pm$ 3.4 <i>p</i> < 0.00001	92.3 $\pm$ 3.7 <i>p</i> < 0.00001	91.9 $\pm$ 4.5 <i>p</i> < 0.00001

Systolic blood pressure reached a peak at dobutamine doses of 20 mcg/kg/min. Diastolic blood pressure decreased slightly from 76.3 ± 12.2 mmHg to 65.6 ± 16.6 mmHg, *p* = 0.007. Heart rate increased from 72 to 135 bpm, *p* < 0.00001. Global strain increased from -19.6 to -23.7%, *P* < 0.00001. Global work index (GWI) decreased from 2393.3 ± 503.4 to 1864.7 ± 424.4 mmHg', *p* < 0.0004. Global constructive work (GCW) decreased from 2681.7 ± 549.6 to 2152.6 ± 521.7 mmHg', *p* = 0.001. Global wasted work (GWW) increased from 78.8 ± 56.5 to 128.3 ± 45.2 mmHg%, *p* < 0.003. Global work efficacy (GWE) decreased from 96.1 ± 3.1 to $91.9 \pm 4.5\%$, *p* < 0.00001. Changes in the strain pressure loops during dobutamine

stress echocardiography show (Fig. 2) that a small increase in strain during the cardiac cycle results in a steeper elevation of left ventricular pressure during the increment of dobutamine doses.

Discussion

Dobutamine stress echocardiography is considered a good pharmacological alternative to stress echocardiography, within a generally acceptable safety profile (6). Despite it, 7.6% of studies are stopped prematurely because of side effects (7). Accelerated protocols of short-term high dose dobutamine infusion were suggested (8) in the past. Modern protocols with atropine delivery at 20 and 30 mcg/kg/min were developed to shorten the study and to improve its tolerability (5). The various effects of dobutamine during dobutamine stress echocardiography are dose-dependent. Dobutamine has an affinity for cardiac α - and β -receptors. β_1 -receptors stimulation, results in an increase in myocardial contractility, atrioventricular conduction, and heart rate. Stimulation of α -adrenergic receptors results in systemic vasoconstriction, raises blood pressure, and increased myocardial contractility. Stimulation of vascular β_2 -receptors induces coronary and peripheral arteriolar vasodilatation. The inotropic effect of dobutamine predominates in low doses, and the chronotropic effect develops in high doses [9]. Mechanics of cardiac contraction was evaluated recently with novel speckle tracking derived parameter, myocardial work index (4, 10–13). Evaluation of cardiac deformation parameters at stress echocardiography imaging up to recently was limited due to suboptimal speckle tracking quality and to inability to track endocardial border at high heart rates. Improved quality of modern echocardiography systems makes echocardiography images more suitable for speckle tracking imaging analysis. Few studies evaluated strain behaviour during exercise stress echocardiography [14] and dobutamine stress echocardiography [15–17]. Recently, a novel myocardial work index was investigated in patients during exercise stress echocardiography [18, 19, 20], and in athletes after a half marathon [21]. Results of our study showed that despite improvement in global strain, all the parameters of myocardial work deteriorated during dobutamine stress echocardiography: global work index, global constructive work, global work efficacy, and global wasted work. During normal exercise stress echocardiography, deterioration was found only in global wasted work [19] and global work efficacy [19, 21]; the global work index improved [19, 21] and global constructive work improved [19], Table 3.

Table 3
Cardiac Effects of Dobutamine and Exercise
Stress Echocardiography

Cardiovascular parameters	DSE	ESE
Heart Rate	↑	↑
Systolic Blood Pressure	↑	↑
Global Strain	↑	↑
Global Work Index	↓	↑
Global Constructive Work	↓	↑
Global Wasted Work	↑	↑
Global Work Efficacy	↓	↓
DSE-Dobutamine Stress Echocardiography		
ESE - Exercise Stress Echocardiography		

Our results show that the cardiac influence of dobutamine is different from the effect of exercise during stress echocardiography. In addition to increases in heart rate, systolic blood pressure, and global strain, other indicators of myocardial function are impaired during dobutamine stress echocardiography. The possible physiological explanation is stimulation of α -receptors by high-dose dobutamine with the subsequent vasoconstriction and increased afterload. Our results indicate that pharmacological stress can overload the heart, age-related heart rate may not be the optimal criterion for interrupting the dobutamine infusion, and probably, the test can be terminated earlier.

Conclusions

As we found in our study, during normal dobutamine stress echocardiography, although global myocardial strain increases, all the specific parameters of myocardial work index deteriorate. We can suppose, that calculated target heart rate may be not the optimal parameter to define termination of dobutamine infusion. Myocardial work index and global strain can be used too. Further investigations of myocardial work index variables in patients with ischemia is needed.

Declarations

Funding. No funding was received.

Compliance with ethical standards

Conflict of interest. There is no conflict of interests.

Our study was done in accordance with the ethical standards of the local Helsinki Committee.

Informed consent was not required due to the retrospective nature of the work with patients' files anonymously.

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Figures

Figure 1

Changes in myocardial work index parameters during normal dobutamine stress echocardiography. SBP – systolic blood pressure, DBP – diastolic blood pressure, HR – heart rate, GS – global strain, GCW – global constructive work, GWW – global wasted work, GWE – global work efficacy, GWI – global work index.

Figure 2

Pressure-strain loops during normal dobutamine stress echocardiography. LVP – left ventricular pressure. MVC – mitral valve closure, MVO – mitral valve opening, AVC – Aortic valve closure, AVO – aortic valve opening. Small rise of strain results in steeper increment of LV pressure during dobutamine stress echocardiography.