The Use of Rate of Increase of Intraventricular Pressure During Isovolumetric Contraction (dP/dt) in Assessment of Left Ventricular Function in Acute Coronary Syndrome

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ABSTRACT:

BACKGROUND:

Acute coronary syndrome (ACS) is the clinical manifestation of acutely diminished coronary arterial blood supply. The rate of increase of intraventricular pressure during isovolumetric contraction (left ventricular dP/dt) represents the rate of change of pressure during ejection.

OBJECTIVE:

The aim of this study is to evaluate the usefulness of the rate of increase of intraventricular pressure during isovolumetric contraction (dP/dt) in assessment of left ventricular function in patients with acute coronary syndrome and its relation to certain clinical and echocardiographic features.

PATIENTS AND METHODS:

The study is a cross sectional study including 50 patients with an established diagnosis of acute coronary syndrome. The study was performed in Baghdad Teaching Hospital during the period between 2/2/2013 and 5/3/2014. History was taken from all patients and recoded using a specially prepared questionnaire paper. Left ventricular internal dimensions at end diastole (LVIDd) and end systole (LVIDs) were measured using M-mode echocardiography to asses left ventricular systolic function (ejection fraction). Pulse Doppler tracing of the transmitral flow velocities and tissue Doppler image (TDI) mitral annular velocities were obtained from the apical four-chamber view to assess left ventricular diastolic function. Doppler-derived dP/dt was determined from mitral regurgitation (MR) spectral flow

RESULTS:

The study included 50 patients (31 males and 19 females, mean age of 65.26 ± 5 years). Low dP/dt values were found in 42 patients (84%). Low dP/dt values were found more in the age group (51-60 yrs) (p value < 0.05). The mean age of patients with low dP/dt (<1000) was (65.62 ± 5yrs) and that of patients with normal dP/dt (≥ 1000) was (63.38 ± 5 yrs) with no significant difference (p value > 0.05). Low dP/dt value was significantly associated with smoking and positive family history and not significantly associated with male sex, hypertension, and diabetes mellitus. No significant association was found between low dP/dt value and type of presentation of acute coronary syndrome (p value > 0.05) or ejection fraction (p value > 0.05). It was significantly associated with LV diastolic dysfunction, left atrial size, left atrial pressure, and left ventricular size (p value < 0.05).

CONCLUSION:

The use of dP/dt is useful for evaluating left ventricular function in patients with acute coronary syndrome.

KEY WORDS: dP/dt, echocardiography, acute coronary syndrome

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INTRODUCTION:

Coronary heart disease (CHD) is the leading cause of death worldwide. In patients who present to the emergency department with acute chest pain, an acute coronary syndrome (ACS) is frequently present.[1] A plentiful arterial circulation is required for an effective myocardial function during both systole and diastole. This supply-demand coupling

is accomplished through regional matching of the arterial supply to a particular portion of the myocardium. Arterial circulation of the heart consists of two parts: (1) large epicardial coronary arteries which serve as conduit vessels, and (2) medium-size and small intramyocardial coronary arterioles which serve as resistance vessels regulating the amount of coronary flow according to myocardial metabolic needs. Perturbation in any portion of this arterial tree will lead to a regional myocardial dysfunction. [1]

One of the most sensitive indices of contractility is the rate of increase of intraventricular pressure during isovolumetric contraction (left ventricular dP/dt and arterial dP/dt). dP/dt represents the rate of change of pressure during ejection. [2]

Left ventricle dP/dt is less load-dependent and is theoretically a more accurate reflection of LV function. [3] It has been shown that cardiac contractility and dP/dt decrease during acute myocardial ischemia. Among the various cardiac contractility parameters, left ventricular (LV) ejection fraction (EF) and maximum dP/dt (dP/dt_{max}) are the simplest and mostly used together. [2]

The aim of this study is to evaluate the usefulness of the rate of increase of intraventricular pressure during isovolumetric contraction (dP/dt) in assessment of left ventricular function in patients with acute coronary syndrome and its relation to certain clinical and echocardiographic features.

PATIENTS AND METHODS:

The study included patients referred to the coronary care unit with an established diagnosis of acute coronary syndrome (unstable angina, non ST-elevation myocardial infarction and ST-elevation myocardial infarction). The study was performed in Baghdad Teaching Hospital during the period between 2/2/2013 and 5/3/2014. The patients were selected based on their diagnosis of acute coronary syndrome and presence of mitral regurgitation. Patients with primary mitral valvular regurgitation and patients with acute coronary syndrome without mitral regurgitation were not included in the study. History was taken from all patients and recoded using a specially prepared questionnaire paper. The study was conducted in compliance to the medical ethical rules and all participants have given their consent.

Echocardiographic examination was conducted by independent operator in the coronary care unit. The echocardiography machines used in this work were Vivid S6, Vivid E9 and Philips CX-50 with transducers operating at 2.5, 3.5 and 4.4 MHz. Left ventricular internal dimensions at end diastole (LVIDd) and end systole (LVIDs) were measured using M-mode echocardiography to asses left ventricular systolic function (ejection fraction). Pulse Doppler tracing of the transmitral flow was obtained from the apical four-chamber view during quiet respiration with the patients lying on the left lateral position. The early transmitral flow velocity E and the peak late velocity A were measured, from which E/A was calculated.

Classification of severity of left ventricular size and function and left atrial size was based on the recommendations for chamber quantification from the American society of echocardiography's guidelines and standards committee and the chamber quantification writing group, developed in conjunction with the European association of echocardiography, a branch of the European society of cardiology. [4]

Mitral annulus velocity measurements were obtained from the apical four-chamber view by tissue Doppler imaging (TDI), using a 1-2 mm sample volume placed at the lateral side of the mitral valve annulus. The TDI mitral annular velocities were measured including the early annular velocity (Ea). All TDI velocities were taken as an average of the lateral readings of five cardiac cycles. The mean values of Ea velocities were used to calculate the $E_{(mitral)}/E_{(annular)}$ (Em/Ea) ratio which is considered representative of left atrial pressure. [5]

Doppler-derived dP/dt was determined as follows: the two points on the mitral regurgitation (MR) spectrum corresponding to 1 m/s and 3 m/s were identified. These points corresponded to LV-left atrial pressure gradients of 4 mm Hg and 36 mm Hg respectively using the modified Bernoulli equation. Doppler-derived dP/dt was defined as dP/dt = 36-4/dT = 32 mm Hg/dt (Fig. 1). A dP/dt value of less than 1000 was considered abnormally low. [5]

Results were analyzed using Med Calc version 12.5.0.0. All values were expressed as mean values with standard deviation ±1. The comparison between the mean values for both groups was tested by paired student's t-test. p value<0.05 was considered as the level of significance.

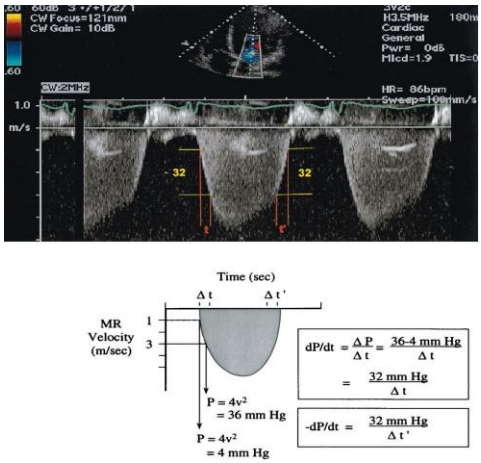

Figure 1: Determination of Doppler-derived dP/dt from the continuous-wave Doppler spectrum of the MR jet. P: pressure; t: time; v: velocity.

RESULTS:

The study included 50 patients (31 males and 19 females) with a mean age of 65.26 ± 5 years (range 52-83 years). Males constituted 62% of study sample and females constituted 38%.Low dP/dt value was found in 42 patients (84%) and normal value was found in 8 patients (16%).The mean age of patients with low dP/dt (<1000) was (65.62 ± 5yrs) and that of patients with normal (dP/dt ≥ 1000) was (63.38 ± 5 yrs) and the difference was statistically insignificant (p value >0.05). The age distribution of patients with low dP/dt value is shown in table (1). Low dP/dt values were found more in the age group (51-60 yrs) followed by age group (71-80 yrs). The association between low dP/dt value and age was statistically significant (p value <0.05).

The association between low dP/dt value and cardiovascular risk factors is shown in table (1). It was significantly associated with smoking and positive family history and not significantly associated with male sex, hypertension, and diabetes mellitus. The association between low dP/dt value and type of presentation of ACS is shown in table (1). The association was statistically not significant (p value > 0.05).

The associations between low dP/dt value and left ventricular size and function are shown in table (2). The association was statistically significant (p value < 0.05) with increasing left ventricular size and worsening left ventricular diastolic function while it was statistically insignificant (p value <0.05) with ejection fraction.

There was a significant association between low dP/dt value and increasing left atrial size and pressure as shown in table (3).

Table 1: Relation between demographic and clinical characteristics and low dP/dt.

Variable	(dP/dt<1000) No.	Percentage	P value
Age group (years) (range 52-83 years)			
51-60	19	38	<0.05
61-70	9	18	
71-80	10	20	
81-90	4	8	
Sex			
Male	25	50	>0.05
Female	17	34	
Smoking			
Yes	10	20	< 0.05
No	32	64	
Family history			
Negative	12	24	< 0.05
Positive	30	60	
Hypertension			
Negative	23	46	>0.05
Positive	19	38	
Diabetes mellitus			
Negative	19	38	>0.05
Positive	23	46	
Type of presentation			
Unstable Angina	11	22	< 0.05
NSTE-MI	10	20	
ST-MI	21	42	

Table 2: Relation between left ventricular size and functions and low dP/dt.

Parameter	(dP/dt<1000) No.	Percentage	P value
LV diastolic dimension (mm)[4]			
Normal (4.2-5.9)	2	4	<0.05
Mild dilatation (6.0-6.3)	7	14	
Moderate dilatation (6.4-6.8)	10	20	
Severe dilatation ≥6.9	23	46	
LV ejection fraction (%)[4]			
<35%	6	12	>0.05
35-44%	14	28	
45-54%	9	18	
>55%	13	26	
LV diastolic function[4]			
Normal	5	10	< 0.05
Grade 1 diastolic dysfunction	12	24	
Grade 2 diastolic dysfunction	21	42	
Grade 3 diastolic dysfunction	4	8	
Grade 4 diastolic dysfunction	0	0	

Table 3: Relation between left atrial size and pressure and low dP/dt.

Parameter	(dP/dt<1000) No.	Percentage	P value
LA dimension (mm)[4]			
Normal(≤ 40 mm)	1	2	<0.05
Mild dilatation (41-45 mm)	5	10	
Moderate dilatation(46-50 mm)	14	28	
Severe dilatation(≥ 51 mm)	22	44	
LA Pressure (mmHg)[5]			
< 8	5	8	<0.05
8-15	12	24	
>15	25	50	

DISCUSSION:

The non invasive evaluation of left ventricular systolic and diastolic functions remains an important goal in cardiology. According to the Bernoulli equation, analysis of the Doppler mitral regurgitant velocity profile allows accurate calculation of the left ventriculoatrial pressure difference throughout systole and early diastole before mitral valve opening. [6] Widespread use of isovolumetric variables of left ventricular systolic and diastolic functions was limited in large part by the need for invasive, high fidelity pressure measurements at cardiac catheterization; but nowadays, these important indexes of ventricular function can be quantified noninvasively by using Doppler echocardiography in patients with mitral regurgitation. [6]

It has been shown that cardiac contractility decreases with a subsequent decrease in left ventricular dP/dt and arterial dP/dt during acute ischemia. It was reported that a substantial decrease in arterial dP/dt occurred during coronary balloon occlusion. [2]

In this study, the mean age of the study sample was 65.26 ± 5 yrs which is not different from other studies in acute coronary syndrome. [6,7] This is expected finding as age is a major risk factor for ischemic heart disease and acute coronary syndrome. [8]

Males constituted 62% of study sample and females constituted 38%. Another study done by William W et al found similar results. [3] This finding is expected since male sex is a major risk factor for ischemic heart disease. [8]

Low dP/dt value was found in 42 patients (84%) with acute coronary syndrome. Kiyotake Ishikawa et al found low dP/dt values in 75% of patients with ST-elevation myocardial infarction (STEMI) [9] while Iván J Núñez-Gil et al found low values in 79% of patients with non ST-elevation myocardial infarction (NSTMI). [7] This can be explained by the fact that acute ischemia leads to abnormalities of myocardial contractile relaxation functions leading to elevation of left ventricular filling pressures and consequently low dP/dt value which represent the rate of change of pressure difference between the left ventricle and left atrium. [10]

Low dP/dt values were found more in the age group (51-60 yrs) followed by age group (71-80 yrs). Similarly, Kiyotake Ishikawa et al found low dP/dt values more an age group of 50-70 yrs.[9]

In this study, it was shown that low dP/dt was significantly associated with smoking history and presence of positive family history of ischemic heart disease. The association with smoking was similarly found by Kiyotake Ishikawa et al [9] in acute coronary syndrome while Theodore J et al did not demonstrate significant association between smoking and low dP/dt values in patients with congestive heart failure.[3] Smoking is a major risk factor for ischemic heart disease and in the current study 33 out of 50 patients were current smokers. The association between positive family history and low dP/dt values was found by Kiyotake Ishikawa et al [9] in patients with acute myocardial infarction, while Theodore J et al found no association in patients with heart failure [3]. The difference may be due to different selection criteria of study populations between different studies.

This study did not demonstrate significant association of low dP/dt with male sex, hypertension and diabetes mellitus. Iván J Núñez-Gil et al showed significant association between

low dP/dt values and hypertension and diabetes mellitus.[7] Kiyotake Ishikawa et al showed significant association between low dP/dt values and male sex and hypertension but no significant association with diabetes mellitus.[9] Namsik Chung et al and Aydin Yildirim et al showed significant association with diabetes mellitus but not male sex. [10,11] These studies were done in different study populations as some of them were done in patients with acute STEMI; others were done in patients with NSTMI, dilated cardiomyopathy and heart failure.

In this study low dP/dt values were more commonly found in patients with acute STEMI (42%) followed by unstable angina (22%) and NSTMI (20%) but the association did not reach the level of significance. The association with STEMI may be explained by the fact that STEMI causes more damage to LV myocardium than other types of acute coronary syndrome and consequently more LV dysfunction and elevation of LV filling pressure leading to low dP/dt values. [10]

In this study, it was shown that low dP/dt values were significantly associated with LV size with more prevalence of low values with increasing LV size. This is in agreement with other studies by Kiyotake Ishikawa et al and Aydin Yildirim et al. [9,11]. On the other hand, Theodore J et al did not show this association. [3] It is known that an increase in LV size occurs before LV dysfunction being evident by echocardiography as measured by LV ejection fraction but it is now known that LV function as measured by LV ejection fraction is relatively insensitive marker of LV function when compared with newer techniques like tissue velocity, tissue tracking, and tissue strain and strain rate. [10] Therefore, LV dysfunction is more probably present in the stage of the increase in LV size and this could explain the strong association between LV size and low dP/dt values in this study which makes dP/dt measurement an accurate and sensitive indicator of LV function in patients with ACS.

In this study, there was no significant association between low dP/dt values and ejection fraction. In fact, a significant proportion of patients (26%) with low dP/dt values had normal ejection fraction. This indicates that dP/dt may be more sensitive than or at least complementary to ejection fraction as measures of LV function. In the current era of tissue Doppler and tissue strain and strain rate imaging, it was found that ejection fraction is not as accurate and sensitive indicator of LV function as previously thought.[10] Other studies showed similar results to our findings in larger number of patients with heart failure. [3,12,13] On the other hand, Kiyotake Ishikawa et al concluded that EF is a more accurate measure of systolic dysfunction than dP/dt in patients with MI and attributed this superiority to the well-known preload dependence of dP/dt.[9] The LV ejection fraction is the simplest and most used parameter and the best available prognostic predictor in patients with systolic heart failure.[14] However, EF is afterload dependent; it decreases to zero regardless of contractile state when afterload is infinite. On the other hand, dP/dt is a simple indicator of cardiac contractility but this index is known to be preload dependent and it is also affected by the heart rate.[15] Both EF and dP/dt thus have advantages and limitations, and they are often reported simultaneously in studies while it is not clear if they are complementary or redundant [9].

A significant association was found between low dP/dt value and diastolic dysfunction and most (42%) of the patients had grade II diastolic dysfunction. A similar observation was found by Wallace AG et al. [15] Another study[16] did not show this association and this may be due to use of different criteria for diagnosing and grading of diastolic dysfunction in different studies. The presence of LV diastolic dysfunction means an increase of LV filling pressure and decrease between pressure difference between left ventricle and left atrium and consequently a decrease of MR dP/dt[10].

In this study, a significant association was found between left atrial size and low dP/dt values where most patients with low dP/dt values had larger LA size. A similar finding was observed by Iván J Núñez-Gil et al and Namsik Chunget al. [7,10] A similarly significant association was observed in the current study between low dP/dt values and left atrial pressure as measured by echocardiography and more patients with low dP/dt values had higher left atrial pressure. This observation was also found by G S Bargiggia et al [16] in their study measuring both parameters invasively. We did not find a study measuring LA pressure by echocardiography and comparing it with dP/dt value at the time of writing this paper. The association between LA size, LA pressure and dP/dt value can be explained by the

same explanation mentioned above regarding the association with LV diastolic dysfunction.

CONCLUSION:

The use of dP/dt is useful for evaluating left ventricular function in patients with acute coronary syndrome.

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