European Review for Medical and Pharmacological Sciences 2012; 16(Suppl 1): 16-21

Atrioventricular plane displacement: does it predict in-hospital outcome after acute myocardial infarction?

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Abstract. – *Background and Objectives:* **Atrioventricular plane displacement is a well-accepted method for assessment of left ventricular systolic function. We explored the ability of atrioventricular plane displacement to predict in-hospital outcome in patients with acute ST-elevation myocardial infarction.**

Materials and Methods: **Ninety three patients with acute ST-elevation myocardial infarction were prospectively included. Each patient underwent trans-thoracic echocardiography for measurement of the ejection fraction by the Simpson's method. Atrioventricular plane displacement was measured from the apical views, assessed in four different regions, namely, the septal, lateral, anterior and inferior ones, and the mean value was calculated. We used a cutoff value to classify patients into a group with atrioventricular plane displacement < 10 mm and another with atrioventricular plane displacement ≥ 10 mm. Similarly, patients were classified into those with ejection fraction < 40% and others with ejection fraction ≥ 40%. All patients were followed-up during their in-hospital stay for the occurrence of major adverse cardiac events, namely, death, heart failure, complex ventricular arrhythmias, post-infarction angina, or mechanical complications.**

Results: **During the follow-up period (3±1.5 days), major adverse cardiac events occurred in 16 (72.7%) patients with atrioventricular plane displacement < 10 mm, and in 6(8.5%) patients with atrioventricular plane displacement ≥ 10 mm, $p < 0.01$. An atrioventricular plane displacement below 10 mm was able to predict the occurrence of major events with a sensitivity 72.7%, specificity 91.5%, negative predictive value (NPV) 91.5%, positive predictive value (PVP) 72.7%. Similarly, an ejection fraction below 40% predicted the occurrence of major events with a sensitivity 72.7%, specificity 90.1%, NPV 91.4%, PVP 69.6%. We found a strong correlation between an atrioventricular plane displacement < 10 mm, and an ejection fraction < 40%, $p < 0.01$.**

Conclusion: **Left atrioventricular plane displacement below 10 mm, can adequately predict the occurrence of in-hospital major adverse cardiac events after acute ST-elevation myocardial infarction, with a high correlation with ejection fraction below 40%.**

Key Words:

Atrioventricular plane displacement, Myocardial infarction, Outcome.

Introduction

There is a good evidence that prognosis after myocardial infarction is closely related to the extent of left ventricular (LV) systolic dysfunction[1]; traditionally expressed as the ejection fraction (EF). However, methods to assess the EF have their drawbacks. Estimation of ejection fraction by linear M-mode measurements is unreliable when LV contraction is asymmetrical in the presence of gross regional wall motion abnormality, which is the usual case after myocardial infarction[2]. Biplane two-dimensional estimation of EF tolerates asymmetry but requires a good image quality for adequate tracing of the endocardial borders, which is not always obtainable[3].

Left ventricular pump function was long considered the result of action of the circumferentially oriented myocardial fibers. However, the complexity of myocardial fiber orientation and the importance of longitudinal fibers were thoroughly described in man since the early 1980s[4]. Since the distance between the apex and the chest surface is constant during the cardiac cycle, the left atrioventricular plane displacement (AVPD), measured from the surface of the thorax using trans-thoracic two-dimensional-guided M-mode echocardiography, equals longitudinal axis shortening of the LV[5].

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A growing body of data has demonstrated the crucial importance of the LV longitudinal systolic function. In one study, based on cardiac magnetic resonance evaluation, left AVPD contributed for almost 60% of the stroke volume in healthy subjects, athletes, and in patients with dilated cardiomyopathy[6]. Moreover, decreased left AVPD predicted the onset of hypertension[7], and was an independent predictor of cardiovascular risk in hypertensive patients[8]. Additionally, determination of left AVPD guided the timing of surgery in patients with chronic aortic regurgitation whose LV dimensions and EF were not conclusive[9].

In a prospective study design, we sought to explore the ability of left AVPD to predict in-hospital outcome in patients with acute ST-elevation myocardial infarction.

Materials and Methods

Patient Selection

We enrolled 93 consecutive patients admitted to our Critical Care Unit during the period from October 2008 to July 2009, with the diagnosis of acute ST segment elevation myocardial infarction (STEMI). The diagnosis of STEMI was based on 12-lead electrocardiogram showing persistent ST segment elevation ≥ 1 mm in at least two contiguous leads plus one of the following: (1) prolonged chest discomfort typical of myocardial ischemia, (2) elevated cardiac biomarkers: CK MB and/or troponin more than twice the upper limit of normal lab reference. We excluded patients with transient ST segment elevation due to coronary artery spasm, non- STEMI, and left bundle branch. Before inclusion, an informed consent was obtained from each patient and the study protocol was reviewed and approved by our local Institutional Human Research Committee as it conforms to the ethical guidelines of the 1975 Declaration of Helsinki, as revised in 2000.

Definition of Risk Factors

The presence of hypertension was defined as a systolic blood pressure ≥ 140 mmHg and/or a diastolic blood pressure ≥ 90 mmHg, previously recorded by repeated non-invasive office measurements, which leads to life-style modification or antihypertensive drug therapy. Diabetes mellitus was defined according to the diagnostic criteria described by the American Diabetes Association as a fasting plasma glucose ≥ 126 mg/dl, and/or a 2-hour postload glucose ≥ 200 mg/dl, or specific anti-diabetic drug therapy.

Pharmacological Management

Patients eligible for reperfusion therapy (presenting within 12 hours after symptom onset, or presenting thereafter with persistent symptoms), received pharmacological reperfusion therapy in the form of streptokinase infusion 1,500,000 units over 30-60 minutes. All standard anti-ischemic medications were allowed and remained unchanged during the study period.

Echocardiographic Evaluation

Assessment of LV systolic function was performed in all patients by trans-thoracic echocardiography within 24 hours of admission. Doppler echocardiography was performed using a General Electric Vivid 7 Pro cardiac ultrasound machine (General Electric, Norway). A 2.5 MHz phased array probe was used to obtain standard two-dimensional, M-mode and Doppler images. Patients were examined in the left lateral recumbent position using standard parasternal long axis and apical views. AVPD was measured by two-dimensional-guided M-mode as the distance covered by the atrioventricular plane (delineated at the mitral valve annulus) from the position most remote from the apex (at the onset of systole), to the position closest to the apex (at end-systole). It was assessed from the septal and lateral segments in apical 4-chamber view, and from the anterior and inferior segments in apical 2-chamber view, being calculated from an average of 2 cardiac cycles at each site, in patients with sinus rhythm, and 4 cycles in patients with atrial fibrillation. The mean value of AVPD was calculated for each patient. Additionally, LV EF was measured using the biplane Simpson's method from the apical 4- and 2-chamber views. Patients were stratified according to the AVPD into a group with a mean AVPD < 10 mm, and another with a mean AVPD ≥ 10 mm. Alternatively, they were classified according to the two-dimensional LV EF into a group with EF < 40%, and another with EF ≥ 40%.

In-Hospital Follow-up

Patients were followed up during their in-hospital course for the occurrence of major adverse cardiac events (MACE) namely: death, heart failure, complex ventricular arrhythmias (sustained

ventricular tachycardia or ventricular fibrillation), early post-infarction angina, or mechanical complications. Heart failure was diagnosed clinically according to the standard criteria. Complex ventricular arrhythmias were documented by monitor ECG strip or by 12-lead ECG recording. Early post-infarction angina was defined as recurrent typical chest discomfort during hospital admission following relief of that of the index myocardial infarction. Mechanical complications (recorded by echocardiography) included: acute mitral regurgitation, rupture of the interventricular septum, LV pseudo-aneurysm formation, and rupture of the LV free wall.

Statistical Analysis

All continuous variables were presented as means ± SD, if they were normally distributed. Data were tested for normal distribution using the Kolmogorov-Smirnov test. Categorical variables were described with absolute and relative (percentage) frequencies. Comparisons between the 2 subgroups regarding the frequency of occurrence of a single major event was studied by χ^2 test or Fisher's exact test (two-tailed) if the expect count in any cell was < 5. Comparisons between the 2 subgroups regarding the frequency of occurrence of the total MACE was performed using the logistic regression analysis, for either the AVPD or the EF. All tests were two-sided and a probability value of $p < 0.05$ was considered statistically significant. Analyses were performed with SPSS version 12.0 statistical package (SPSS Inc., Chicago, IL, USA).

Results

A total of 93 patients were included in the current study, with a definite diagnosis of STEMI on admission. Baseline characteristics of the overall cohort as well as the two individual subgroups are shown in Table I. The mean age was 55.2 ± 11 years, 68 (73%) being males. The duration of hospital stay ranged from 1 to 11 (mean 3 ± 1.5) days. When patients were classified according to the AVPD, no statistically significant difference was found between patients with AVPD < 10 mm, and those with AVPD ≥ 10 mm as regards any of the baseline characteristics, except for hypertension which was found more frequently in patients with AVPD < 10 mm, in comparison with their counterparts ($p < 0.05$), and peak CK MB level which was significantly higher among those with AVPD < 10 mm ($p < 0.01$).

Table II shows echocardiographic characteristics of the whole series. The mean value of the LV EF was 51.5 ± 10.8%, while the mean value of the AVPD was 12 ± 2.6 mm for the whole study cohort. Seventy one patients (76.3%) had a mean AVPD ≥ 10 mm, while 22 (23.7%) had a mean AVPD < 10 mm.

Table I. Baseline characteristic of the whole study cohort and the 2 subgroups.

	Whole Cohort (N = 93)	AVPD ≥10 mm (N = 71)	AVPD <10 mm (N = 22)	*P* value
Age (years)	55.2 ± 11	53 ± 11	59 ± 12	> 0.05
Males	68 (73.1)	52 (73.2)	16 (72.7)	> 0.05
Smoking	68 (73.1)	46 (64.8)	16 (72.7)	> 0.05
Diabetes	44 (47.3)	29 (40.8)	15 (68.2)	> 0.05
Hypertension	46 (49.5)	29 (40.8)	17 (77.3)	< 0.05
Prior MI	6 (6.5)	2 (2.8)	4 (18.2)	> 0.05
Prior PCI	3 (3.2)	1 (1.4)	2 (9.1)	> 0.05
Prior CABG	0 (0)	0 (0)	0 (0)	–
Systolic BP (mmHg)	125 ± 11	125 ± 11	122 ± 12	> 0.05
Diastolic BP (mmHg)	80 ± 8	80 ± 6	80 ± 8	> 0.05
Heart rate (bpm)	80 ± 7	80 ± 7	81 ± 8	> 0.05
CK MB (ng/ml)	124 ± 81	112 ± 79	160 ± 73	< 0.01
Fibrinolytic therapy	81 (87.1)	65 (91.5)	16 (72.7)	> 0.05

All continuous variables are presented as mean ± SD, while categorical variables are presented as numbers (percentage). MI indicates myocardial infarction; PCI: percutaneous coronary intervention; CABG: coronary artery bypass grafting; BP: blood pressure; bpm; beats per minute; AVPD: atrioventricular plane displacement.

Table II. Echocardiographic characteristics of the whole study cohort.

Echocardiographic parameter	Mean ± SD
EDD (mm)	49.9 ± 7.4
ESD (mm)	35.7 ± 7.1
2-D EF (%)	51.5 ± 10.8
Mean AVPD (mm)	12 ± 2.6
AVPD septal (mm)	11.6 ± 3.2
AVPD lateral (mm)	12.5 ± 3.4
AVPD anterior (mm)	11.8 ± 3
AVPD inferior (mm)	12 ± 3.4

EDD indicates end-diastolic diameter; ESD: end-systolic diameter; 2D EF: two-dimensional ejection fraction; AVPD:atrioventricular plane displacement.

On follow-up, one female patient (age 80 years) died 1 day after admission, as a result of rupture of the interventricular septum. As shown in Table III, 17 patients developed heart failure, 10 had complex ventricular tachyarrhythmias, and 6 experienced early post-infarction angina. When patients were stratified according to the AVPD, heart failure was significantly less frequent among patients with AVPD ≥ 10, mm compared with those with AVPD < 10 mm [1 (1.4%) versus 16 (72.7%), $p < 0.01$]. Similarly, ventricular tachyarrhythmias and post-MI angina were significantly less frequent in this subgroup of patients [4 (5.6%) versus 6 (27.3%), $p < 0.01$; and 2 (2.8%) versus 4 (18.2%), $p < 0.05$, respectively].

Patients with AVPD < 10 mm had a significant excess of all MACE as compared to those with AVPD ≥ 10 mm [16 (72.7%) versus 6 (8.5%), $p < 0.01$]. AVPD < 10 mm was able to predict the occurrence of MACE with a sensitivity 72.7%, specificity 91.5%, negative predictive value (NPV) 91.5%, positive predictive value (PPV) 72.7%.

Likewise, when patients were stratified according to the LV EF, patients with an EF < 40% had significantly more MACE than their counterparts with an EF ≥ 40% [16 (69.6%) versus 6 (8.6%), $p < 0.05$]. LV EF < 40% predicted the occurrence of MACE with a sensitivity 72.7%, specificity 90.1%, NPV: 91.4%, PPV: 69.6%.

Finally, we found a close correlation between an AVPD < 10 mm and an LV EF < 40%, $p < 0.01$.

Discussion

Left ventricular systolic function is the single most powerful predictor of outcome after myocardial infarction. In this sense, fractional shortening and Teichholz EF are not reliable when LV contraction is asymmetrical[2,10], in which case, two-dimensional EF can be reliable, however, it is not always accessible[3]. AVPD reflects global LV longitudinal systolic function despite LV asymmetry since it is determined in four different regions of the left ventricle, namely, the septal, lateral, anterior and inferior regions. It demands very little of image quality since the atrioventricular plane is highly echogenic and examination is rapidly performed[11]. In a late-breaking study, standard M-mode imaging of the left AVPD was shown as a reliable method for assessment of LV longitudinal systolic function[12]. Other lines of evidence suggest that left AVPD decreases in patients with heart failure and preserved EF[13] and in patients with diabetes mellitus and/or hypertension[14].

In this investigation we explored the value of left AVPD to predict in-hospital complications after STEMI. To the best of the Authors' knowledge, the current study was the first to use a cutoff value of 10 mm of the mean AVPD to stratify patients

Table III. Major adverse cardiac events in the whole study cohort and the 2 subgroups.

	Whole Cohort (N = 93)	AVPD ≥ 10 mm (N = 71)	AVPD < 0 mm (N = 22)	*P* value
Death	1 (1.1)	0 (0)	1 (4.5)	_
Heart failure	17 (18.3)	1 (1.4)	16 (72.7)	< 0.01
Ventricular arrhythmias	10 (10.8)	4 (5.6)	6 (27.3)	< 0.01
Post-MI angina	6 (6.5)	2 (2.8)	4 (18.2)	< 0.05
Mechanical complications	1 (1.1)	0 (0)	1 (4.5)	_

Data are expressed as numbers (percent). AVPD indicates atrioventricular plane displacement; MI, myocardial infarction.

into two subgroups: a group with an AVPD < 10 mm with a high risk of in-hospital complications, and another with an AVPD ≥ 10 mm with a relatively lower such a risk. Assessment of AVPD was easy, highly reliable, reproducible and readily achievable in virtually all patients. Similarly, other studies found that the easy visualization and simplicity of recording of AVPD make it a valuable non-invasive tool for LV function evaluation following acute STEMI[15,16].

The two subgroups were homogeneous concerning baseline characteristics; however, hypertension was more frequent in patients with an AVPD < 10 mm. This may relate to the effect of longstanding hypertension on LV systolic function[7]; these patients might have had already compromised LV systolic function, and consequently, a superimposed myocardial infarction was less well tolerated. In addition, peak CK MB level was significantly higher among those with AVPD < 10 mm. Considering that fibrinolytic therapy was equally given to the 2 subgroups, peak CK MB would reflect the extent of infarction and thus, a higher peak CK MB denotes a larger area of myocardial necrosis, that would translate into a worse systolic function.

In the current study, an AVPD below 10 mm was able to predict the occurrence of in-hospital MACE with an acceptable sensitivity (72.7%) and a high specificity (91.5%), both being comparable to those of an LV EF < 40%. In agreement, Brand et al[16] found that in patients with acute myocardial infarction, an AVPD in the lowest quartile (AVPD < 8 mm) carries a hazard ratio of 3.1 for overall mortality, and a hazard ratio of 3 for mortality/heart failure hospitalizations on long-term follow-up, when compared with patients in the upper 3 quartiles.

Finally, we found that a cutoff value of 10 mm for the left AVPD strongly correlated with an LV EF of 40%. Similarly, Alam[17] previously reported that a mean value of AVPD of 10 mm or more had a high sensitivity (95%) and specificity (82%) for defining a normal LV EF (≥ 50%). He concluded that in acute myocardial infarction, LV function can be assessed non-invasively using the AVPD.

Conclusions

The results of this investigation current study suggest that a left AVPD below 10 mm can adequately predict the occurrence of in-hospital MACE after acute STEMI, being highly correlated with an EF below 40%.

Limitations of the Study

Our findings are based on a single center study with a relatively small sample size of the cohort, a fact that makes it difficult to generalize our results to all patients admitted with acute myocardial infarction. Multicenter studies using the same protocol and examining a larger number of patients are needed. Finally, as hospital stay was very short (3 days on the average), information about in-hospital mortality – although important – might not be the best way to mirror the patients' real prognosis. Follow-up should be extended for a longer period before one can safely predict the prognosis on the intermediate and long term.

References

1) Taylor GJ, Humphries JO, Mellits ED, Pitt B, Schulze RA, Griffith LS, Achuff SC. Predictors of clinical course, coronary anatomy and left ventricular function after recovery from acute myocardial infarction. Circulation 1980; 62: 960-970.
2) Teichholz LE, Kreulen T, Herman MV, Gorlin R. Problems in echocardiographic volume determinations; echocardiographic angiographic correlations in the presence or absence of asynergy. Am J Cardiol 1976; 37: 7-11.
3) Willenheimer R, Cline C, Erhardt L, Israelsson B. Left ventricular atrioventricular plane displacement: an echocardiographic technique for rapid assessment of prognosis in heart failure. Heart 1997; 78: 230-236.
4) Greenbaum RA, Ho SY, Gibson DG, Becker AE, Anderson RH. Left ventricular fiber architecture in man. Br Heart J 1981; 45: 248-263.
5) Hoglund C, Alam M, Thorstrand C. The atrioventricular valve plane displacement in healthy persons, an echocardiographic study. Acta Med Scand 1988; 244: 557.
6) Carlsson M, Ugander M, Mosén H, Buhre T, Arheden H. Atrioventricular plane displacement is the major contributor to left ventricular pumping in healthy adults, athletes, and patients with dilated cardiomyopathy. Am J Physiol Heart Circ Physiol 2007; 292: H1452-1459.
7) Blendea D, Duncea C, Bedreaga M, Crisan S, Zarich S. Abnormalities of left ventricular long-axis function predict the onset of hypertension independent of blood pressure: a 7-year prospective study. J Hum Hypertens 2007; 21: 539-545.

8) Ballo P, Barone D, Bocelli A, Motto A, Mondillo S. Left ventricular longitudinal systolic dysfunction is an independent marker of cardiovascular risk in patients with hypertension. Am J Hypertens 2008; 21: 1047-1054.

9) Helin LM, Tamás E, Nylander E. Preoperative longitudinal left ventricular function by tissue Doppler echocardiography at rest and during exercise is valuable in timing of aortic valve surgery in male aortic regurgitation patients. J Am Soc Echocardiogr 2010; 23: 387-395.

10) Starling MR, Crawford MH, Sorensen SG, Levi B, Richards KL, O'Rourke RA. Comparative accuracy of apical biplane cross-sectional echocardiography and gated equilibrium radionuclide angiography for estimating left ventricular size and performance. Circulation 1981; 63: 1075-1084.

11) Alam M, Höglund C, Thorstrand C, Philip A. Atrioventricular plane displacement in severe congestive heart failure following dilated cardiomyopathy or myocardial infarction. J Intern Med 1990; 228: 569-575.

12) Mondillo S, Galderisi M, Ballo P, Marino PN; Study Group of Echocardiography of the Italian Society of Cardiology. Left ventricular systolic longitudinal function: comparison among simple M-mode, pulsed, and M-mode color tissue Doppler of mitral annulus in healthy individuals. J Am Soc Echocardiogr 2006; 19: 1085-1091.

13) Ren YQ, Feng W, Liu L, Xia W, Qu XF. Reduced left ventricular systolic atrioventricular plane displacement in heart failure patients with preserved ejection fraction. Zhonghua Xin Xue Guan Bing Za Zhi 2009; 37: 809-812.

14) Ballo P, Cameli M, Mondillo S, Giacomin E, Lisi M, Padeletti M, Bocelli A, Galderisi M. Impact of diabetes and hypertension on left ventricular longitudinal systolic function. Diabetes Res Clin Pract 2010; 90: 209-215.

15) Alam M, Hoglund C, Thorstrand C. Serial echocardiographic studies following thrombolytic treatment in myocardial infarction with special reference to atrioventricular plane displacement. Clin Cardiol 1992; 15: 30-36.

16) Brand B, Rydberg E, Ericsson G, Gudmundsson P, Willenheimer R. Prognostication and risk stratification by assessment of left atrioventricular plane displacement in patients with myocardial infarction. Int J Cardiol 2002; 83: 35-41.

17) Alam M. The atrioventricular plane displacement as a means of evaluating left ventricular systolic function in acute myocardial infarction. Clin Cardiol 1991; 14: 588-594.