Association of Stage of Left Ventricular Diastolic Dysfunction with P Wave Dispersion and Occurrence of Atrial Fibrillation after First Acute Anterior Myocardial Infarction

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Objectives: The aim of this study was to investigate the association of stage of left ventricular diastolic dysfunction after acute myocardial infarction (AMI) with P maximum, P dispersion, and atrial fibrillation (AF) occurrence rate.

Background: The occurrence of AF following AMI is frequently associated with a left ventricle restrictive filling pattern. Increased P dispersion is also associated with the occurrence of AF after AMI. But, the relation between the stage of left ventricular diastolic dysfunction and the P wave measurements after AMI has not yet been investigated.

Methods: Electrocardiograms of 90 patients with first anterior AMI were recorded on admission, and P wave measurements were performed. The left ventricular diastolic functions were evaluated by transthoracic echocardiography. On the basis of mitral inflow, subjects were stratified into three left ventricular diastolic filling patterns. All patients were monitored continuously for the detection of AF in the Coronary Care Unit.

Results: Thirty patients had a normal filling pattern (33.3%) (NF group), 37 had impaired relaxation (41.1%) (IR group), and 23 had pseudonormal/restrictive filling pattern (25.6%) (PN/R group). P maximum was longer in the PN/R group (103 ± 12 ms) compared with the NF group (94 ± 9 ms, $P = 0.019$), but no significant difference was found between PN/R and IR (96 ± 13 ms, $P > 0.05$) groups, and between NF and IR groups ($P > 0.05$). There was no significant difference for P minimum among the groups ($P > 0.05$). P dispersion was longer in the PN/R group (35 ± 6 ms) than in the NF (26 ± 7 ms, $P < 0.001$) and IR groups (26 ± 6 ms, $P < 0.001$), but not different between the NF and IR groups ($P > 0.05$). Occurrence of AF was significantly more frequent in the PN/R group (52.2%) than in the NF (16.7%, $P = 0.007$) and IR groups (10.8%, $P = 0.001$). Frequency of AF was not different between the NF and IR groups ($P > 0.05$). In multivariate analyses, the stage of diastolic dysfunction was independently associated with P maximum, P minimum, P dispersion, and the occurrence of AF ($P < 0.001$, $P = 0.035$, $P < 0.001$, and $P = 0.002$, respectively).

Conclusions: P maximum and P dispersion are increased, and AF occurrence risk is higher in patients with pseudonormal/restrictive filling pattern after first anterior AMI. The stage of diastolic dysfunction is an independent predictor of P wave measurements and AF occurrence.

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P wave duration; P wave dispersion; diastolic dysfunction; acute myocardial infarction

Atrial fibrillation (AF) is a frequent complication of acute myocardial infarction (AMI), which is associated with increased in-hospital and long-term mortality and morbidity rates.¹⁻⁵ Previously, it was demonstrated that the occurrence of AF following

AMI is frequently associated with advanced diastolic dysfunction.⁶

It is shown that P wave durations and P dispersion on the electrocardiogram, both measured in a very early period of AMI, are useful in predicting

AF.^{7,8} But, the relation between the stage of left ventricular diastolic dysfunction and the P wave measurements has not yet been evaluated.

This study investigates the association of the stage of left ventricular diastolic dysfunction with P wave measurements and the occurrence of AF after AMI.

METHODS

Study Population

The study group consisted of 90 consecutive patients (mean age 58 ± 10 years; 10 women) with the first anterior AMI who fulfilled the following criteria: (1) chest pain lasting >30 min and admission to the coronary care unit <24 hours from the onset of chest pain; (2) ST-segment elevation ≥ 2 mm at least in two anterior electrocardiographic leads; and (3) transient elevation of creatine kinase and/or creatine kinase-MB isoenzyme levels.

The exclusion criteria were rhythm and conduction abnormalities on admission or during echocardiographic examination, prior pacemaker implantation, abnormal thyroid function, valvular heart disease, moderate-to-severe mitral regurgitation according to the method of Helmcke et al.,⁹ cardiomyopathies, congenital heart diseases, lung diseases and pulmonary hypertension, abnormal serum electrolyte values, receiving digitalis or any antiarrhythmic drugs, history of paroxysmal AF, myocardial infarction, collagen disease, chronic renal failure and cardiac surgery, and a deficient acoustic window.

Electrocardiograms and routine blood samples were performed on admission and everyday during hospitalization. Thyroid function tests were studied in all patients. All patients were examined by careful auscultation at least twice daily. Detection of pericardial rub during the first 72 hours after admission was considered diagnostic of infarction-related pericarditis. The diagnosis of pericardial rub was made after confirmation by at least two cardiologists.

All patients were monitored continuously in the Coronary Care Unit, and AF observed or triggered by the rate-dependent alarm system during the first 7 days was evaluated. The diagnosis of AF was performed in the presence of the following criteria in salvos of ≥ 10 beats: (1) absence of P waves; (2) coarse or fine fibrillatory waves; and (3) completely irregular R-R intervals occurring according

to the available 12-lead electrocardiography recordings and reports of monitoring.

Thrombolytic therapy was administered in patients with no contraindications and with symptoms ≤ 12 hours in duration. Aspirin was given on admission and 300 mg/day thereafter to all patients. All patients received heparin during hospitalization. Patients also received the following medications during and after hospitalization: nitrates, 90%; angiotensin-converting enzyme inhibitors, 78%; β -blockers, 64%; and statins, 93%.

Electrocardiography and P Wave Measurements

A 12-lead surface electrocardiogram was obtained from all patients in the supine position on admission using a Hewlett-Packard Electrocardiograph Sanborn Series (Chine) machine. The electrocardiograms were recorded at a paper speed of 50 mm/s and 1 mV/cm standardization. All patients breathed freely but were not allowed to speak during the electrocardiogram recordings. Two investigators without knowledge of patients' clinical status measured the P wave durations manually. To improve accuracy, measurements were performed with calipers and magnifying lens for defining the electrocardiogram deflection.¹⁰⁻¹² The onset of P wave was defined as the junction between the isoelectric line and the start of P wave deflection and the offset of the P waves as the junction between the end of the P wave deflection and the isoelectric line.¹³ P maximum in any of the 12-lead surface electrocardiograms was calculated and used as a marker of prolonged atrial conduction time. P dispersion, defined as the difference between P maximum and P minimum, was calculated from the 12-lead electrocardiogram.

Echocardiography

Echocardiography was performed within 24 hours after onset of chest pain by using Sonos 5500 ultrasound machine (Hewlett-Packard, Andover, MA) with a 2.5-MHz transducer.

Left ventricle end-diastolic and end-systolic volumes were determined from apical two- and four-chamber views by using the Simpson biplane formula according to the recommendations of the American Society of Echocardiography.¹⁴ The ejection fraction was calculated as (end-diastolic – end-systolic volume)/end-diastolic volume.

The left ventricle was divided into 16 segments to calculate the wall motion score index.¹⁴ Segmental wall motion was graded as follows: normal motion at rest (score = 1); hypokinetic-marked reduction in endocardial motion and systolic thickening (score = 2); akinetic-virtual absence of inward motion and systolic thickening (score = 3); and dyskinetic-paradoxical wall motion away from the center of the left ventricle in systole (score = 4). The wall motion score index was calculated by summing the scores for each segment and dividing by the number of segments analyzed.

Pulsed Doppler mitral flow velocity was obtained by placing the sample volume between the tips of the mitral leaflets in the apical four-chamber view.¹⁵ The Doppler beam was aligned as perpendicularly as possible to the plane of the mitral annulus. In each patient, measurements from five cardiac cycles were obtained and averaged. The following variables were measured: E, A, E/A ratio, and deceleration time of early filling (DT). The isovolumetric relaxation time (IRT) defined as the time from aortic valve closure to mitral valve opening was assessed by simultaneously measuring the flow into the left ventricle outflow tract and mitral inflow by Doppler.¹⁶

According to the Doppler mitral flow velocity profile, as expressed by the mitral DT and IRT, the patients were assigned to the following three filling pattern: (1) DT > 140 ms and IRT < 100 ms, representing a normal filling pattern; (2) DT > 140 ms and IRT ≥ 100 ms, representing impaired relaxation pattern; and (3) DT ≤ 140 ms, suggesting either a pseudonormal or restrictive filling pattern. The subdivision and cutoff were predefined and based on previous studies in normal subjects and previous combined echocardiographic Doppler and invasive hemodynamic studies.^{17–23}

In order to determine pericardial effusion, two-dimensional echocardiography was repeated on the third day of hospitalization according to the method of Horowitz et al.²⁴ An epicardial-pericardial separation that persisted throughout the cardiac cycle (D pattern) was considered diagnostic of pericardial effusion.

Reproducibility

Intraobserver and interobserver variabilities of P wave duration were 3 ± 5% and 4 ± 5% and those of P wave dispersion were 3 ± 4% and 3 ±

5% (absolute difference divided by mean value of measurements).

Statistical Analysis

Results are expressed as mean ± 1 standard deviations or percentages. One-way analysis of variance (ANOVA) with a post hoc test by Bonferroni was used for continuous variables among groups. Comparisons of the results were made using the chi-square test for categorical variables. Student's independent samples *t*-test was used to compare the difference between the two groups. Multiple linear regression analysis and multivariate logistic regression analysis were performed to determine the independent relationship between left ventricular systolic and diastolic function to the P wave measurements and AF. For multivariate logistic regression analysis, factors with a P value < 0.1 in univariate analysis were selected. Statistical analyses were performed using SPSS software (Version 9.05, SPSS, Inc., Chicago, IL). A P value of < 0.05 was considered statistically significant.

RESULTS

AF occurred in 21 of 90 patients (23.3%). In most of the patients, AF occurred on the first and second days of AMI. AF occurred in 5 patients (24%) on day 1, 10 patients (48%) on day 2, 4 patients (19%) on day 3, and 2 patients (9%) after day 3. All episodes of AF converted to sinus rhythm spontaneously (14 patients) or by medical (5 patients) and electrical cardioversion (2 patients).

Among the 90 patients with AMI, 30 had a normal filling pattern (33.3%) (NF group), 37 had impaired relaxation (41.1%) (IR group), and the remaining 23 had a pseudonormal/restrictive filling pattern (25.6%) (PN/R group). Table 1 summarizes the clinical characteristics of the three groups. In a comparison of the groups, there were no significant differences in age, gender, arterial hypertension, diabetes mellitus, smoking, heart rate, systolic and diastolic blood pressures, and frequency of pericarditis. Mean peak serum creatine kinase level was higher in the PN/R group compared with the other groups. There was no difference between the groups in the use of thrombolytics, nitrates, angiotensin-converting enzyme inhibitors, β-blockers, and statins.

Table 1. Patients Characteristics

	NF (n = 30)	IR (n = 37)	PN/R (n = 23)	P value
Age (years)	56 ± 9	58 ± 10	59 ± 12	0.461
Gender (M/F)	28/2	32/5	20/3	0.637
Arterial hypertension (%)	13 (43)	13 (35)	10 (44)	0.734
Diabetes mellitus (%)	6 (20)	6 (16)	4 (17)	0.921
Smoking (%)	20 (67)	20 (54)	15 (65)	0.515
Heart rate (beats/min)	78 ± 10	79 ± 21	86 ± 18	0.236
SBP (mmHg)	132 ± 23	134 ± 44	129 ± 26	0.855
DBP (mmHg)	80 ± 18	74 ± 22	77 ± 15	0.460
Peak creatine kinase(U/L)	1985 ± 637	2416 ± 865	3369 ± 1189	*
Pericardial rub or effusion (%)	8 (27)	10 (27)	8 (35)	0.425
Thrombolytics (%)	18 (60)	21 (57)	12 (52)	0.721
ACE inhibitors (%)	24 (80)	28 (76)	18 (78)	0.912
Beta blockers (%)	21 (70)	22 (60)	15 (65)	0.667
Nitrates (%)	25 (83)	33 (89)	23 (100)	0.131
Statins (%)	29 (97)	35 (95)	20 (87)	0.187

ACE = angiotensin-converting enzyme; DBP = diastolic blood pressure; IR = patients with impaired relaxation filling pattern; NF = patients with normal filling pattern; PN/R = patients with pseudonormal/restrictive filling pattern; SBP = systolic blood pressure.

*P < 0.001 NF versus PN/R; P = 0.001 IR versus PN/R; P = 0.152 NF versus IR.

Echocardiograms

Echocardiographic results are shown in Table 2. End-systolic and end-diastolic volumes were larger, EF was lower, and wall motion score index was higher in the PN/R group than in the other groups. There was no significant difference in these parameters in comparison to the NF and IR groups. E velocity of mitral inflow was lower in the IR group compared with the NF and PN/R groups. The A velocity was lower in the PN/R group than in the NF and IR groups. In the PN/R group, E/A ratio was

highest, IRT and DT were shortest. In the IR group, E/A ratio was lowest, IRT and DT were longest.

P Wave Measurements and Frequency of AF According to Left Ventricular Filling Pattern

P maximum was longer in the PN/R group (103 ± 12 ms) compared with the NF group (94 ± 9 ms, P = 0.019), but no significant difference was found between the PN/R and IR (96 ± 13 ms, P > 0.05) groups, and between NF and IR groups (P > 0.05).

Table 2. Echocardiographic Parameters in Patients with Acute Anterior Myocardial Infarction According to Their Left Ventricular Filling Pattern

	NF (n = 30)	IR (n = 37)	PN/R (n = 23)
End-systolic volume (ml)	64 ± 17	60 ± 18	88 ± 18*
End-diastolic volume (ml)	116 ± 23	114 ± 20	138 ± 25**
Ejection fraction (%)	45 ± 7	48 ± 10	36 ± 6*
WMSI	1.8 ± 0.3	1.8 ± 0.3	2.4 ± 0.3*
Left atrial dimension (mm)	27 ± 4.3	27 ± 5.0	29 ± 4.7
E (cm/s)	68 ± 14	56 ± 15***	69 ± 12
A (cm/s)	65 ± 18	75 ± 21	41 ± 14*
E/A	1.12 ± 0.39	0.78 ± 0.22 [#]	1.86 ± 0.61*
Deceleration time (ms)	182 ± 22	234 ± 46 ^{##}	122 ± 15*
IRT (ms)	79 ± 10	109 ± 13 ^{##}	70 ± 9 ^{###}

A = late diastolic mitral inflow velocity; E = early diastolic mitral inflow velocity; IRT = isovolumetric relaxation time; WMSI = wall motion score index; other abbreviations as in Table 1.

*P < 0.001 versus NF and IR; [#]P = 0.002 versus NF; **P = 0.002 versus NF and P < 0.001 versus IR; ^{##}P < 0.001 versus NF; ***P = 0.004 versus NF, and P = 0.002 versus PN/R; ^{###}P = 0.02 versus NF, and P < 0.001 versus IR.

Figure 1. P wave durations, P dispersion, and frequency of AF according to left ventricular filling pattern. AF=atrial fibrillation; IR=patients with impaired relaxation filling pattern; NF=patients with normal filling pattern; PN/R, patients with pseudonormal/restrictive filling pattern.

(Fig. 1). There was no significant difference for P minimum among the groups ($P > 0.05$). P dispersion was longer in the PN/R group (35 ± 6 ms) than in the NF (26 ± 7 ms, $P < 0.001$) and IR groups (26 ± 6 ms, $P < 0.001$), but was not different in the NF and IR groups ($P > 0.05$).

The occurrence of AF was significantly more frequent in the PN/R group (in 12 of 23 patients (52.2%)) than in the NF (in 5 of 30 patients (16.7%), $P = 0.007$), and IR groups (in 4 of 37 patients (10.8%), $P = 0.001$). The frequency of AF was not different between the NF and IR groups ($P > 0.05$) (Fig. 1).

P Wave Measurements and Percentages of Filling Patterns in Patients with and without AF

When comparing the patients with AF and those without, P maximum and P dispersion were significantly higher in patients with AF than in those without (103 ± 11 ms vs 95 ± 12 ms, $P = 0.013$; 35 ± 7 ms vs 27 ± 7 ms, $P < 0.001$, respectively). There was no significant difference between the patients with AF and those without AF for P minimum (68 ± 10 ms vs 69 ± 8 ms, $P = 0.78$, respectively). Comparisons of patients with and without AF are shown in Table 3.

Patients with AF had a more frequent pseudonormal/restrictive filling pattern than patients with-

Table 3. P Wave Durations, P Dispersion, and Frequencies of Filling Patterns in Patients with and without AF

	With AF (n = 21)	Without AF (n = 69)	P value
P maximum (ms)	103 ± 11	95 ± 12	0.013
P minimum (ms)	68 ± 10	69 ± 8	0.780
P dispersion (ms)	35 ± 7	27 ± 7	< 0.001
Normal filling	5 (23.8%)	25 (36.2%)	0.216
Impaired relaxation	4 (19.0%)	33 (47.8%)	0.016
Pseudonormal/restrictive filling	12 (57.1%)	11 (15.9%)	< 0.001

AF, atrial fibrillation.

out AF (12 of 21 patients (57.1%) vs 11 of 69 patients (15.9%), $P < 0.001$, respectively) (Table 3 and Fig. 2). Whereas the frequencies of the normal filling pattern and impaired relaxation filling pattern were lower in patients with AF than in those without (23.8% vs 36.2%, $P = 0.216$; 19.0% vs 47.8%, $P = 0.016$, respectively).

Multivariate Analysis

In multiple linear regression analysis (Table 4), the stage of diastolic dysfunction and A velocity, but not any other variable, were independently associated with P maximum and P minimum. There was no independent relationship between any systolic or diastolic variable and P dispersion. But

Figure 2. Frequencies of filling patterns in patients with and without AF. For abbreviations see Figure 1.

Table 4. Multiple Linear Regression Analysis Between Left Ventricular Function Parameters and P Maximum, P Minimum, and P Dispersion in Patients with First Anterior Acute Myocardial Infarction

	For P Maximum P Value	For P Minimum P Value	For P Dispersion P Value
E	0.940	0.543	0.475
A	0.014	0.027	0.174
E/A	0.690	0.593	0.980
Deceleration time	0.155	0.067	0.998
IRT	0.322	0.389	0.556
Stage of diastolic dysfunction	< 0.001	0.035	< 0.001
End-systolic volume	0.898	0.616	0.351
End-diastolic volume	0.950	0.415	0.305
Ejection fraction	0.248	0.535	0.221
WMSI	0.783	0.411	0.102

For abbreviations see Table 2.

only the stage of diastolic dysfunction was independently associated with P dispersion.

Multivariate logistic regression analysis showed that the stage of left ventricular diastolic dysfunction, DT, and WMSI were independent predictors of AF. P wave measurements were not independent predictors of AF. The results of multivariate regression analysis are presented in Table 5.

DISCUSSION

Previously, it has been reported that advanced diastolic dysfunction⁶ and increased P dispersion^{7,8} are associated with the occurrence of AF following AMI, but the present study is the first to examine the association of the stage of left ventricular diastolic dysfunction with P wave durations and P dispersion after anterior AMI. Our results indicate that the pseudonormal/restrictive filling pattern after AMI is frequently associated with an increased P maximum and P dispersion, and higher AF occurrence rate.

P wave durations and P dispersion on standard electrocardiogram are noninvasive markers of intraatrial conduction disturbances, which are believed to be the main electrophysiological cause of AF. Rios et al.²⁵ reported an increased incidence of P wave abnormalities with more severe coronary artery disease and more severe left ventricular dysfunction. It is shown that P dispersion is increased in patients with AF after AMI.^{7,8} And it was also reported that patients with AF after AMI have often advanced diastolic dysfunction,⁶ which is a result of an increase in left atrial pressure. Hence, it is expected that P dispersion increases in

patients with pseudonormal/restrictive filling pattern. In our study, we found that P maximum and P dispersion were increased, and AF occurrence rate was higher in the PN/R group compared with the NF and IR groups (Fig. 1). When comparing the NF and IR groups, no significant differences were found in P wave measurements and AF occurrence rate. This results suggest that P maximum, P dispersion, and AF occurrence risk increase in the presence of elevated left atrial pressure as in the pseudonormal/restrictive filling pattern²⁶ but not in impaired relaxation pattern.

Increasing evidence suggests that the atrial stretch induced by increased atrial pressure may precipitate AF through an effect on atrial refractoriness.^{27,28} It is also reported that AF is induced by increased left atrial pressure and advanced left ventricular dysfunction in patients with AMI.²⁹ Furthermore, Celik et al.⁶ showed that the occurrence of AF after AMI is often associated with a higher restrictive filling pattern rate. In our study as well, the frequency of AF was higher in the PN/R group than in the NF and IR groups. In the pseudonormal/restrictive filling pattern, chamber compliance of the left ventricle decreases, and left atrial pressure increases.²⁶ Thus, theoretically, increased AF risk is expected due to increased left atrial pressure in patients with a pseudonormal/restrictive filling pattern. In the PN/R group, as diastolic functions, left ventricular systolic function was also worse than in the NF and IR groups.

In patients in whom AF occurred ≥ 24 hours after the onset of myocardial infarction, advanced left ventricular dysfunction plays an important role in the development of AF, the incidences of anterior

Table 5. Univariate and Multivariate Predictors of Atrial Fibrillation in Patients with First Anterior Acute Myocardial Infarction

Factors	Univariate P Value	Multivariate		
		Chi-Square	β Coefficient	P Value
Age	0.5205	—	—	—
Gender	0.7919	—	—	—
Diabetes	0.4121	—	—	—
Hypertension	0.4172	—	—	—
SBP	0.6803	—	—	—
DBP	0.8342	—	—	—
Heart rate	0.5377	—	—	—
Peak creatine kinase	0.0324	4.2	0.1241	0.213
Left atrial diameter	0.7251	—	—	—
E	0.0001	6.5	0.3462	0.119
A	0.0032	8.1	−0.1229	0.327
E/A	0.0001	11.9	0.9376	0.455
Deceleration time	0.0003	28.6	0.0541	0.043
IRT	0.1699	—	—	—
Stage of diastolic dysfunction	0.0006	92.8	0.7234	0.002
End-systolic volume	0.0147	5.3	0.1830	0.423
End-diastolic volume	0.2742	—	—	—
Ejection fraction	0.0012	7.4	0.0101	0.124
WMSI	0.0001	84.8	0.7303	0.020
P maximum	0.0166	12.6	0.0697	0.720
P minimum	0.7771	—	—	—
P dispersion	0.0002	21.1	−0.0369	0.359
Total	—	247.6	—	< 0.0001

For abbreviations see Tables 1 and 2.

infarcts and congestive heart failure are high, pulmonary capillary wedge pressure is increased, and a marked decrease in ejection fraction is noted.³⁰ In the current study, we found that AF occurred after the first day of AMI in most of the patients (76%), and often in patients with advanced left ventricular dysfunction.

In multivariate linear regression analysis, while the stage of diastolic dysfunction and A velocity were independently related to P maximum and P minimum, only the stage of diastolic dysfunction was independently related to P dispersion. There was not independent relation between systolic function parameters and P wave measurements.

Multivariate logistic regression analysis showed that the strongest variable that is independently predictive of AF occurrence was the stage of diastolic dysfunction. The other variables that were independent predictors of AF were WMSI and DT. While only diastolic function variables were independently associated with P wave measurements, systolic and also diastolic function pa-

rameters were independently associated with AF occurrence.

In some studies, it is reported that pericarditis is one of the factors associated with the occurrence of AF in AMI.^{29,31,32} But, in our study, there was no significant difference in the frequency of pericardial rub or effusion among groups, probably due to the small number of patients.

In the comparison of patients with AF and without, P maximum, P dispersion, and the percentages of patients with a pseudonormal/restrictive filling pattern were higher in those with AF. These findings are consistent with the previous studies.^{6–8}

Limitations

Our study had several limitations. First, invasive measurements were not performed in this echocardiographic study of the group of patients. However, the echocardiographic Doppler measurements used in this study have previously been related to invasive measures of cardiac function.^{17–23} Another important limitation of our study involves the small

number of patients. Large prospective studies are needed to establish an association of the stages of left ventricular diastolic dysfunction with P wave measurements and AF. Furthermore, patients with valvular heart disease were excluded in this study. The application of our findings to patients with valvular heart disease, especially with mitral regurgitation, should also be studied in the future. We measured left atrial diameter in this study as a parameter of its size, but atrial dilatation may be eccentric.³³

CONCLUSION

The results of our study demonstrated that the pseudonormal/restrictive filling pattern after first anterior AMI is associated with an increased P maximum, P dispersion, and higher risk for AF. Multivariate analysis showed that the stage of left ventricular diastolic dysfunction is independently associated with P wave measurements, and an independent predictor of AF.

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