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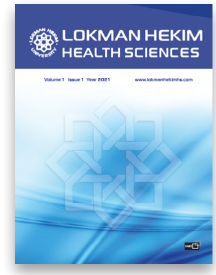

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Relationship between Coronary Artery Tortuosity and Left Ventricular Diastolic Functions

Koroner Arter Tortuositesi ve Sol Ventriküler Diyastolik Fonksiyonlar Arasındaki İlişki

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Abstract

Introduction: We aimed to evaluate the relationship between coronary tortuosity and left ventricular relaxation disorder using conventional and new diastolic function parameters evaluated with echocardiography.

Methods: A total of 131 patients who underwent coronary angiography for suspected coronary artery disease were included in the study. We compared diastolic function parameters obtained in echocardiography of the patients with coronary artery tortuosity (CAT) and normal coronary arteries.

Results: There was no correlation between conventionally measured diastolic functions and coronary tortuosity. However, we obtained significant findings with new diastolic function parameters such as myocardial performance index (MPI), early mitral inflow velocity, and mitral annular early diastolic velocity (E/e´). Especially, in patients who had moderate or severe coronary tortuosity, there was a significant increase in anterior and septal wall MPI. The E/e´ ratio was found to be significantly higher in patients with moderate–severe coronary tortuosity.

Discussion and Conclusion: CAT is common in invasive cardiology. Tissue Doppler echocardiography may be useful in determining diastolic dysfunction in these patients.

Keywords: Cardiology; Coronary circulation; Echocardiography; Diastolic heart failure; Health care

Coronary artery tortuosity (CAT) is the abnormal coronary artery geometry seen incidentally during coronary angiography.[1] In a study, the frequency was found to be approximately 12%–39%.[2] The etiology and clinical importance are still being discussed. Several hypotheses have been proposed as the cause of coronary tortuosity. CAT has been suggested to be an arterial adaptive response due to smooth muscle and endothelial cell proliferation and migration.[3] In another hypothesis, the elongation and withdrawal mechanism during each heartbeat in the vascular bed was examined, and the importance of elastin in the vessel wall in retraction was mentioned. Especially

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with age, the amount of elastin decreases. Thus, the vessel becomes elongated and curved. Also, the shape of the left ventricle affects vascular geometry, especially in the hypertrophic heart has been reported to be more fold.[4] Several studies have suggested that tortuosity may be associated with coronary ischemia.[5] Although significant coronary artery stenosis is not detected in many patients who underwent coronary angiography with suspected coronary ischemia as a result of the effort stress test and other non-invasive tests, CAT in these patients supports this hypothesis.[6] The proposed mechanism for myocardial ischemia is reduced blood pressure in the distal coronary arteries with tortuosity.[7] There have been many studies about the relationship between atherosclerosis and coronary tortuosity. It has been reported that shear stress due to blood flow in the curved segment accelerates atherosclerosis and causes progression in atherosclerotic plaques.[8]

Left ventricular diastolic dysfunction is common in clinical practice. Diastolic dysfunction is common in patients with advanced age, obesity, coronary artery disease (CAD), hypertension, diabetes, infiltrative diseases (amyloidosis, hemochromatosis, etc.), chronic renal failure, and systolic heart failure. However, there are a few studies documenting the relationship between coronary artery geometry and diastolic dysfunction in the literature. In this study, we aimed to investigate the relationship between coronary tortuosity and left ventricular diastolic dysfunction using more detailed diastolic function parameters compared with previous studies.

Materials and Methods

Study Population

A total of 131 patients who underwent coronary angiography at our Cardiology Department, due to suspicion or diagnosis of obstructive CAD, were included in the study. Detailed anamnesis was obtained from the patients, and physical examinations were performed. Patients were consecutively enrolled.

Patients with inadequate coronary angiography image quality to be evaluated, patients with > 50% coronary artery stenosis, moderate-to-severe valvular disease, prosthetic valve, previous bypass, history of percutaneous coronary angioplasty, patients with acute coronary syndrome, heart failure, left ventricular hypertrophy, pericardial effusion, arrhythmia (atrial fibrillation, ventricular arrhythmia), myocarditis, chronic renal failure, patients under 18 years of age, patients with inadequate echocardiography images, and those who did not sign the consent form were not included in the study.

Coronary Angiographic Evaluation

Coronary angiography was performed using standard shooting techniques with Philips and GE devices in the coronary angiography laboratory in our clinic. It was performed in the presence of invasive cardiologists, and the results, in terms of the presence of CAD, were interpreted. Three main coronary arteries were divided and evaluated into proximal, middle, and distal segments. The most suitable image traces were selected for evaluation. Angiography revealed the left anterior descending artery, circumflex artery, and right coronary artery. Coronary tortuosity was accepted as the presence of three or more directional changes of 45° or more in the trace of the coronary artery during systole and diastole in any of these arteries. The tortuosity is also divided into the following classes:

- slight tortuosity (one change of direction at specified dimensions)
- medium tortuosity (two pieces of direction change)
- serious tortuosity (direction changes of the specified dimensions above and above)

Echocardiographic Evaluation

Echocardiographic examination was performed using Philips HD 11 XE (Philips Healthcare, Eindhoven, Netherlands) echocardiography device. Echocardiographic measurements were performed in the left lateral decubitus position according to the recommendations of the American Society of Echocardiography.[9] Left ventricular end-diastolic diameter, left ventricular end-systolic diameter, wall thickness, left atrial volume, mitral flow parameters E, A, E/A ratio, and E-wave deceleration time (EDT) values were calculated. Septal, lateral, inferior, and anterior mitral annular early diastolic velocity (e´), late (atrial) diastolic mitral annular velocity (a´), systolic mitral annulus velocity (sm), isovolumetric relaxation time (IVRT), ejection time (ET), isovolumetric contraction time (IVCT), and myocardial performance index (MPI) values were calculated by tissue Doppler method, and E/e´ ratio recorded. MPI was calculated by the following formula: MPI = IVCT + IVRT/ET. In all patients, ejection fractions were calculated by the modified Simpson method from apical four chambers.

Statistical Analysis

The data were analyzed using Windows SPSS 22 (Statistical Package for Social Sciences, Inc., Chicago, IL, USA). Categorical variables were expressed as percentages. Numerical variables were presented with mean±standard devi-

Table 1. Demographic and anthropometric characteristics and the existence of concomitant diseases

	Tortuosity (–) (n=47) (mean±SD)	Tortuosity (+) (n=84) (mean±SD)	p
Mean age (years)	56.0±7.2	58.5±6.9	0.19
Diabetes, n (%)	4 (8.5%)	28 (33.3%)	0.02
Hypertension, n (%)	23 (48.9%)	53 (63.1%)	0.11
Smoking, n (%)	13 (27.7%)	5 (6%)	0.001
Women, n (%)	18 (38.3%)	59 (70.2%)	0.001
Male, n (%)	29 (61.7%)	25 (29.8%)	0.001
BMI (kg/m²)	29.4±5.2	30.0±4.3	0.47
Length (cm)	166.4±8.3	162.7±7.5	0.003
Weight (kg)	82.7±9.5	79.6±10.1	0.11
SBP (mmHg)	124.1±12. 5	122.3±11.8	0.39
DBP (mmHg)	74.7±5.4	72.4±6.1	0.18

SD: Standard deviation; BMI: Body mass index, SBP: Systolic blood pressure; DBP: Diastolic blood pressure.

Table 2. Comparison of echocardiographic findings of groups

	Tortuosity (–) (n=47) (mean±SD)	Tortuosity (+) (n=84) (mean±SD)	p
LVEDD (cm)	4.6±1.1	4.4±1.1	0.09
LVESD (cm)	2.7±0.9	2.7±0.9	0.81
IVS (cm)	1.0±0.21	1.0±0.24	0.84
PW (cm)	0.9±0.3	0.9±0.29	0.21
LA (cm)|	3.6±0.9	3.4±0.9	0.06
Mitral E wave (cm/s)	71±15	70±17	0.83
Mitral A wave (cm/s)	79±16	77±18	0.60
E/A	0.9±0.12	0.95±0.11	0.39
EDT (ms)	182±25.2	188±27.5	0.47
EDV (mL)	99±21.3	85±19.9	**0.01**
ESV (mL)	37±9.5	32±8.8	**0.02**
LVEF (%)	61.8±5.1	61.9±4.9	0.86

SD: Standard deviation; LVEDD: Left ventricular end-diastolic diameter; LVESD: Left ventricular end-systolic diameter; IVS: Interventricular septum; PW: Posterior wall; LA: Left atrium; EDT: E wave deceleration time; EDV: End-diastolic volume; ESV: End-systolic volume; LVEF: Left ventricular ejection fraction.

Table 3. Comparison of tissue Doppler echocardiographic findings in groups

	Tortuosity (–) (n=47) (mean±SD)	Tortuosity (+) (n=84) (mean±SD)	p
Septum			
s´ (cm/s)	7.5±1.2	7.5±1.1	0.94
e´ (cm/s)	7.5±1.3	6.8±1.01	0.12
a´ (cm/s)	9.3±0.81	9.1±0.9	0.52
IVRT (ms)	84.9±21.1	86.0±22.3	0.52
ET (ms)	273.0±51.2	259.0±54.2	0.06
IVCT (ms)	75.9±14.7	78.9±15.6	0.44
MPI	0.59±0.12	0.68±0.14	0.20
Lateral			
s´ (cm/s)	8.4±1.1	8.0±0.9	0.61
e´ (cm/s)	9.8±1.08	9.1±1.2	0.18
a´ (cm/s)	10.5±0.87	10.1±0.95	0.37
IVRT (ms)	78.0±12.1	80.5±11.4	0.47
ET (ms)	264.0±52.3	257.0±47.4	0.32
IVCT (ms)	79.9±15.8	79.1±16.5	0.86
MPI	0.61±0.13	0.65±0.18	0.42
Inferior			
s´ (cm/s)	8.5±1.25	8.1±1.71	0.20
e´ (cm/s)	8.5±1.52	7.7±1.64	0.10
a´ (cm/s)	10.7±2.1	10.9±2.3	0.63
IVRT (ms)	81.0±24.5	81.8±26.3	0.81
ET (ms)	271.0±55.3	257.9±49.8	0.04
IVCT (ms)	76.8±18.1	80.5±19.3	0.40
MPI §	0.59±0.14	0.67±0.015	0.24
Anterior			
s´ (cm/s)	7.8±1.21	7.3±1.15	0.22
e´ (cm/s)	8.6±1.42	7.3±1.78	0.01
a´ (cm/s)	9.8±1.91	9.1±1.76	0.11
IVRT (ms)	82.5	89.0	0.07
ET (ms)	266.0±55.45	260.0±50.32	0.38
IVCT (ms)	77.0±19.3	82.0±16.32	0.24
MPI	0.61±0.12	0.71±0.19	0.18

SD: Standard deviation IVRT: Isovolumetric relaxation time; IVCT: Isovolumetric contraction time; ET: Ejection time; MPI: Myocardial performance index.

ation. The Chi-squared and Student's t-tests were used in the analysis. p-values below 0.05 were accepted as statistically significant.

Results

Coronary tortuosity was classified as mild, moderate, and severe tortuous coronary arteries. All groups were classified according to their demographic characteristics (Table 1). Cigarette consumption was found to be lower in patients with CAT (p=0.001). Demographic and anthropometric characteristics and the existence of concomitant diseases were shown in Table 1.

In the comparison of the echocardiographic findings of the groups included in the study, end-diastolic volume (EDV) and end-systolic volume (ESV) values were significantly lower in patients with CAT. There was no significant difference between E, A, EDT, and E/A ratios (Table 2).

TDI measurements of the interventricular septum, lateral, inferior, and anterior walls of all participants were performed. Medial s´, e´, a´, IVRT, ET, IVCT, and MPI values were measured (Table 3).

Table 4. Comparison of E/e´ values of the groups

	Moderate–severe tortuosity (–) (n=86) (mean±SD)	Moderate–severe tortuosity (+) (n = 45) (mean±SD)	p
IVS E/e´	10.4±1.5	11.8±1.7	0.06
Lateral E/e´	8.0±0.9	8.8±1.1	0.19
Inferior E/e´	9.2±1.7	10.2±1.8	0.14
Anterior E/e´	9.4±1.3	11.3±1.6	0.01

SD: Standard deviation.

ET of the inferior wall was significantly longer in the tortuous group and the Em value of the anterior wall was significantly smaller. Anterior wall E/e´ ratio was found to be significantly higher in patients with moderate-to-severe tortuosity (Table 4).

Discussion

CAT is a common condition that cardiologists often meet during coronary angiography. Some patients undergo coronary angiography for chest pain. Although there is no severe stenosis of the coronary arteries, tortuosity is detected. This led researchers to investigate coronary tortuosity. Decreased blood flow distal to tortuous region decelerates the coronary ischemia process. Left ventricular systolic functions have been emphasized, but diastolic functions have been neglected until recently. However, the fact that the number of patients with heart failure with a normal ejection fraction was significantly higher (up to 50% in some publications) led researchers to study left ventricular relaxation and relaxation anomalies.[10–13] In our study, coronary tortuosity was found in approximately 64% of patients. Similarly, in a study by Turgut et al.,[14] tortuosity was found in 52% of 104 patients who underwent coronary angiography. In a study conducted at the University of West Virginia, all coronary angiographies performed for 8 months were examined, and the serious tortuosity rate was found to be 12.75%.[2] As can be seen, there is a significant difference in coronary tortuosity rates between studies. The possible reason for this is the lack of consensus on the diagnosis of coronary tortuosity. In the study conducted at the University of West Virginia, the diagnosis of tortuosity was made by the presence of two 180° shifts in the systole and diastole along all three major arteries.[2] In the study of Turgut et al.,[14] three or more of the direction changes at ≥45° in systole and diastole in all three main arterial lines were defined as severe coronary tortuosity.[14] In another study by Zegers et al.,[4] two or more of the direction changes of ≤120° in any of the main arteries are defined as tortuosity. According to the American Heart Association's coronary stenosis morphology classification in 1998, one angulation was mild, two angles were moderate, and three angles were classified as severe fold according to the number of angles greater than 45° in any major vessel line. In our study, we used the definition of the American Heart Association and determined the tortuosity rate more than the other studies.

There are very few studies in the literature examining the relationship between coronary tortuosity and left ventricular relaxation. In the study of Turgut et al.,[14] 104 patients were examined and 54 (52%) of them had coronary tortuosity. There was no significant difference in the demographic characteristics of the participants in this study. Echocardiographic diastolic functions were compared, and significant differences were found. Patients with coronary tortuosity had shorter E values, longer A values, smaller E/A ratios, longer EDT, and longer IVRT, and these findings were statistically significant.[14] When the demographic findings were compared in our study, the rate of diabetes was significantly higher in patients with coronary tortuosity. The female sex ratio was observed more frequently in patients with coronary tortuosity. There was a significant inverse relationship between smoking and coronary tortuosity. These findings were correlated with previous studies on coronary tortuosity. For example, in a study by Li et al.,[15] 62.8% of the patients who underwent coronary angiography for chest pain and found coronary tortuosity were women. In this study, an inverse relationship was found between smoking and coronary folding, and these data were consistent with our study. Although there was no significant relationship between the existence of diabetes and coronary folding, the p-value was near to the significance level. Also, we found that coronary tortuosity was significantly more frequent in people who had shorter body lengths as a finding not mentioned in previous studies. It is not yet known whether this finding has clinical significance.

The difference of our study from previous studies was the detailed evaluation of interventricular septum, lateral, inferior, and anterior wall in addition to conventional echocardiographic parameters. Also, MPI values and E/e' ratios, which were not previously evaluated, were compared. In our study, when all patients with mild, moderate, and severe coronary folds were collected and compared with those without folds, there was no significant difference in E, A, E/A, EDT, and IVRT detected by Turgut et al.[14] Only apical four-cavity measurements showed that EDV and ESV were significantly smaller in patients with tortuosity.

In TDI, we found that the ET of the inferior wall was longer and the e´ value of the anterior wall was significantly shorter in patients with convoluted lesions. In both Turgut et al.'s[14] study and our study, the small patient population may have revealed this difference. Larger scale studies are needed to clarify and verify this information. E wave showing mitral early filling rate can be affected especially by preload and heart rate variables. However, it has been shown in previous studies that E/e´ is not dependent on preload and is valuable in predicting left ventricular diastolic pressure.[16] In addition, e´ value is shown as the first affected parameter in diastolic dysfunction. We evaluated the E/e´ ratios separately in the septum, lateral, inferior, and anterior walls, which were not evaluated in patients with previous coronary tortuosity and which were valuable in predicting left ventricular end-diastolic pressure. Although there was no significant difference between the groups, we found a tendency toward significance E/e´ value in anterior wall tissue Doppler examination. In addition, when we compared the E/e´ values of the patients with moderate–serious coronary tortuosity and those without coronary tortuosity, we found a statistically significant finding. Anterior wall E/e´ values were significantly higher in patients with moderate–severe coronary tortuosity than those without coronary tortuosity. This may be a specific finding indicating that left ventricular diastolic pressure tends to increase in patients with moderate–severe coronary tortuosity. Further studies with a large number of participants are needed to confirm this finding. In our study, there was no significant difference in the demographic characteristics and initial measurements in echocardiography between patients with moderate–severe tortuosity and those without tortuosity. However, in the evaluation of TDI, anterior and septal MPI values were significantly longer and anterior medial e´ values were smaller. In particular, the smaller anterior medial e´ value may be an early precursor of left ventricular relaxation disorders.

IVRT, which is a sensitive marker indicating impaired relaxation, is a parameter used in MPI measurement. The MPI is thought to be superior to the traditional methods used to show diastolic dysfunctions. In a study, MPI values were measured in diastolic heart failure and systolic heart failure patients, and it was found that the highest values were in systolic heart failure but MPI values were higher in diastolic heart failure patients compared with the control group.[17] Another study by Duzenli et al.,[18] using the tissue Doppler method to measure MPI in healthy individuals and patients with heart failure, showed more accurate information than the traditional pulse flow method. In our study, the anterior MPI values of the patients with moderate–severe coronary tortuosity were significantly higher than those of the control group. We found that there may be a relationship between moderate–severe coronary tortuosity, and left ventricular relaxation disorder can be shown by MPI.

Conclusion

Consequently, anterior and septal wall myocardial MPI values were significantly higher in patients with moderate–severe coronary tortuosity. This finding may be an early marker of left ventricular relaxation disorder. The previously unreported E/E´ ratio was found to be higher in patients with moderate–severe coronary tortuosity compared with the control group, which is important in predicting left ventricular end-diastolic pressure in this study. The present study demonstrated the diastolic dysfunction that cannot be detected by conventional methods in echocardiography, with the help of the aforementioned advanced evaluation methods in the patients with CAT.

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