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Echocardiography

Left Ventricular Strain and Strain Rate Echocardiography Analysis in Patients with Total and Subtotal Occlusion in the Infarct-Related Left Anterior Descending Artery

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Background: Numerous studies show that percutaneous coronary intervention has no clinical benefit in patients with total occlusion. Both regional and global left ventricle (LV) functions may be evaluated in detail by strain (S) and strain rate (SR) echocardiography. The purpose of this study is to evaluate whether S and SR echocardiography may be used to determine the total occlusion. Method: Sixty stable patients who have total or subtotal occlusion in the infarct-related left anterior descending artery were enrolled (Total occlusion group: 35 and subtotal occlusion group: 25 patients). In all patients, LV longitudinal S and SR data were obtained from total 14 segments. Results: S values of middle and apical segments of LV were significantly lower in the total occlusion groups. In SR analysis, middle and apical values of all walls were significantly different between the groups. The total SR of the middle and apical segments was significantly lower in the total occlusion group (respectively, total SR in middle segments: $-3.4 \pm 0.8\%$ vs. $-4.6 \pm 1.0\%$, $P < 0.00001$ and total SR in apical segments: $-1.7 \pm 0.5\%$ vs. $-2.8 \pm 0.6\%$, $P = 0.001$). The total SR values of four walls were also significantly lower in the total occlusion group ($-10.3 \pm 2.0\%$ vs. $-13 \pm 3.1\%$, $P < 0.0001$). For predicting total occlusion, the highest sensitivity levels (84%) were obtained in SR of middle-anterior segment. SR of middle-septum and middle-lateral segments has the highest specificity levels (86%). Conclusion: Total occlusion in stable patients with acute coronary syndrome has an unfavorable effect on the LV regional and global functions. Patients with total occlusion may be identified by S and SR echocardiography. (Echocardiography 2011;28: 203-209)

Key words: strain echocardiography, strain rate echocardiography, total occlusion

Coronary angiographic findings are closely associated with cardiovascular mortality and prognosis in patients with coronary artery disease.[1] The presence of persistent total occlusion in an infarct-related coronary artery is one of the important factors for the decision of revascularization. Previous studies show that percutaneous coronary intervention has no clinical benefit for patients with total occlusion of the infarct-related coronary artery.[2,3] Moreover, it was found that percutaneous intervention may be associated with an increased risk of adverse cardiac events in comparison to optimal medical treatment alone.[4] In summary, previous data suggest that percutaneous coronary intervention for total occlusion is both unnecessary and harmful. Therefore, to reduce unnecessary interventions in such patients, identification or prediction of persistent total occlusion in infarct-related coronary artery should be required.

Strain (S) and strain rate (SR) echocardiography analyses are more sensitive and quantifiable methods for the evaluation of regional and global left ventricle (LV) function than tissue Doppler and conventional echocardiography. It has been previously shown that myocardial contractility, ischemia and viability may be objectively assessed using S and SR echocardiography.[5–8]

The purposes of this study is to evaluate whether tissue Doppler-derived S and SR echocardiography may be used to determine the presence or absence of total occlusion as an noninvasive and quantitative index.

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Methods:

Study Population:

Stable patients with subacute anterior wall myocardial infarction (MI) were screened for enrollment in the study. The diagnosis of MI was established according to American Heart Association criteria.[9] Coronary angiography was performed in all patients within 1–5 days of MI. According to the angiographic results, 60 patients who have total or subtotal occlusion in the infarct-related proximal left anterior descending artery were enrolled (41 men and 19 woman; mean age, 62 ± 12 years). The total occlusion group consisted of 35 consecutive patients with total occlusion in the left anterior descending artery. The subtotal occlusion group consisted of 25 patients with subtotal occlusion in left anterior descending artery.

The exclusion criteria included the following: acute MI, patients who had received thrombolytic or who had percutaneous coronary intervention performed in early term of MI, unstable clinic or any findings suggesting ongoing myocardial ischemia, NYHA class III or IV heart failure, any mechanical complications after MI, shock, a serum creatinine concentration higher than 2.5 mg/dL, significant left main or three-vessel coronary artery disease, any significant stenosis in the right or circumflex coronary artery together with a left anterior descending artery lesion, middle and distal segment lesion in left anterior descending artery, history of an ischemic coronary event or coronary artery disease, cardiac muscle disease, bundle branch block or atrial fibrillation, hemodynamic instability, and inadequate echogenicity. To evaluate baseline myocardial viability, semi quantitative technetium-99 m sestamibi scintigraphy was performed in all patients after admission over 17-segment model. Coronary collateral score was evaluated by the Rentrop collateral system. The study was approved by the local ethics committee. All the patients were informed about the study and their written consent forms were obtained.

Echocardiography:

The echocardiographies were carried out by a cardiology specialist in the echocardiography laboratory in our cardiology department. The echocardiography was performed by Vivid 7 instruments (GE Medical Systems, Milwaukee, WI, USA), with a 2.5 MHz transducer and harmonic imaging. All echocardiography results were obtained during the first day of hospitalization. According to the recommendations of the American Society of Echocardiography,[10] all echocardiographic examinations were performed with the patient lying in the left lateral decubitus position and two-dimensional images were recorded and measured at the apical four- and five-chambers, and parasternal long axis. The LV systolic and diastolic diameters were measured by M-mode echocardiography. The LV ejection fraction was assessed using the modified biplane Simpson's method.

Strain and Strain Rate Echocardiography Analyses:

Tissue Doppler-derived LV systolic longitudinal S and SR data were obtained in four and two chamber apical views as previously described.[11] Recordings were performed at the end of the expirium and involved three consecutive cycles. Fourteen segments were assessed (basal, middle, and apical segments of septum, inferior, lateral and anterior walls and basal and middle segments of anterior septum). Separately, the sums of four basal, middle and apical segments of the septum, inferior, lateral and anterior walls were calculated. Also, the total SR value of 12 segments in four walls (septum, inferior, lateral and anterior) was included in the statistical analysis. All echocardiograms was performed a cardiology specialist. The intra-observer variability for the S and SR echocardiography measurement were 9.1 ± 6.4% and 10.6 ± 8.2%, respectively.

Biochemical Analysis:

Blood samples were obtained at early morning hours following overnight fasting for lipid profiles and other parameters (Thermo Clinical Labsystems, Vantaa, Finland). High sensitive CRP was measured in all patients (N High Sensitivity CRP, Dade-Behring, Newark, NJ, USA) (normal range 0–6 mg/L).

Coronary Angiography:

Conventional coronary angiography was performed with Philips Integris 5000 equipment (Philips Medical Systems, Best, The Netherlands) in patients within 1–5 days after MI. After obtaining images by standard approaches, each angiogram was interpreted by two independent cardiologists. The coronary lesions were classified as either total occlusion or subtotal occlusive lesion. The criterion for total occlusion of the left anterior descending artery was absent antegrade flow, defined as a thrombolysis in myocardial infarction (TIMI) flow grade of 0.

Statistical Analysis:

Data are expressed as mean ± SD or as a percentage. Kolmogorov–Smirnov tests were used to assess the distributions of numeric parameters. Comparisons between the groups were carried out using Student's *t*-test and the chi-square test. Sensitivity and specificity values of S and

SR parameters for predicting total occlusion were estimated using receiver operator characteristic (ROC) curve analysis. The SPSS 17.0 software was used for basic statistical analysis (Version 17, SPSS Inc., Chicago, IL, USA). The cut off levels of specific segments were determined using by using MedCalc 9.2.0.1 (MedCalc Software, Mariakerke, Belgium).

Results:

The mean age was 64.4 ± 10.5 years in the total occlusion group and 59.4 ± 13.5 years in the subtotal occlusion group (P = 0.1). The rate of smoking, hypertension and diabetes mellitus were similar in two groups. The demographic characteristics of patients in groups are shown in Table I.

The degree of stenotic lesions was 100% in the total occlusion group and 77.0 ± 13.7 in the subtotal occlusion groups. Systolic blood pressure was similar in the groups but diastolic blood pressure was significantly higher in patients with total occlusion. (85.4 ± 18 mmHg vs. 76.7 ± 12.5 mmHg, P = 0.04). Patients in the total occlusion group have significantly higher hs-CRP level compared to patients in the subtotal occlusion group (69.2 ± 86.2 mg/dL vs. 22.1 ± 23.3 mg/dL, P = 0.004) Table I. The number of necrotic segment in baseline technetium-99m sestamibi scintigraphy was similar in two group. (Subtotal group: 2.2 ± 2.4 vs. total group: group: 2.4 ± 2.5, P: 0.6). In total occlusion group, 37% of 35 patients have grade 1 collateral flow in occluded left descending artery. However, 12% of 25 patients in subtotal group have grade 1 collateral flow. Other patients in groups has no collateral circulation.

The peak systolic S values in groups are shown in Table II. S values in the total occlusion group were significantly lower in the mid and apical septum, apical lateral, mid and apical inferior and mid anterior septum segments.

In SR analysis, SR values of basal segments were similar in the two groups. However, SR values of mid and apical segments of all walls were significantly different between the two groups (Table III). Differences between the two groups were more prominent in middle segments.

Figure 1 shows the sum of basal, mid and apical segments SR values in the four walls. While the basal segment SR values were similar (P = 0.1), the total SR of the middle and apical segments in the four walls was significantly lower in the total occlusion group (respectively, SR for middle segments: −3.4 ± 0.8% vs. −4.6 ± 1.0%, P < 0.00001, SR for middle segments: −1.7 ± 0.5% vs. −2.8 ± 0.6%, P = 0.001). The total SR values (sum of 12 segments in four walls) were also significantly lower in the total occlusion groups.

TABLE I

The Clinical and Demographic Characteristics of Total and Subtotal Occlusion Groups

	Total Occlusion Group (n: 35)	Subtotal Occlusion Group (n: 25)	P-value: 25
Age (years)	64 ± 10	59 ± 13	0.1
Male/female n (%)	23 (66)	18 (72)	0.4
Hypertension n (%)	18 (51)	8 (32)	0.1
Diabetes mellitus n (%)	15 (43)	6 (24)	0.1
Smoking n (%)	19 (54)	16 (64)	0.3
Cholesterol (mg/dL)			
Total	191 ± 52	196 ± 56	0.8
LDL	116 ± 38	120 ± 31	0.6
HDL	40 ± 10	37 ± 8.7	0.2
Triglyseride (mg/dL)	188 ± 294	197 ± 261	0.9
Hs-CRP (mg/dL)	69 ± 86	22 ± 23	0.004
Blood pressure (mmHg)			
Systolic	136 ± 27	127 ± 24	0.2
Diastolic	85 ± 18	76 ± 12	0.04
Degree of stenosis (%)	100	77 ± 13	<0.001
LV diameters (cm)			
LVSD	3.7 ± 0.5	3.6 ± 0.5	0.7
LVDD	4.9 ± 0.4	4.9 ± 0.5	0.6
IVSD	1.2 ± 0.1	1.2 ± 0.1	0.2
LVEF (%)	35 ± 8	43 ± 8	0.001

Data expressed was mean ± SD or percentage, Hs-CRP = high sensitive C- reactive protein; LV = left ventricle; LVSD = left ventricle systolic diameter; LVDD = left ventricle diastolic diameter; LVEF = left ventricle ejection fraction; P < 0.05 accepted significant.

TABLE II

LV Longitudinal Strain Results of Total and Subtotal Occlusion Groups

Peak Systolic Strain (Seconds^{-1})	Total Occlusion Group (n: 35)	Subtotal Occlusion Group (n: 25)	P
Septum (%)			
Basal	−12.4 ± 4.8	−14.0 ± 4.7	0.2
Middle	−9.0 ± 3.5	−11.8 ± 4.1	0.007
Apical	−5.0 ± 2.1	−8.1 ± 4.2	<0.0001
Lateral wall (%)			
Basal	−17.1 ± 6.3	−16.3 ± 3.3	0.5
Middle	−11.9 ± 4.8	−13.4 ± 2.6	0.1
Apical	−5.8 ± 2.5	−8.3 ± 2.9	0.001
Anterior wall (%)			
Basal	−15.7 ± 4.7	−14.9 ± 3.6	0.4
Middle	−9.2 ± 3.3	−10.1 ± 3.0	0.2
Apical	−5.1 ± 2.7	−6.3 ± 2.8	0.1
Inferior wall (%)			
Basal	−16.0 ± 4.9	−16.2 ± 4.4	0.9
Middle	−12.5 ± 4.6	−15.1 ± 3.9	0.02
Apical	−6.5 ± 3.3	−9.8 ± 4.6	0.002
Anterior septum (%)			
Basal	−9.7 ± 3.3	−10.8 ± 3.0	0.1
Middle	−6.6 ± 2.4	−9.7 ± 4.3	0.001

$P < 0.05$ accepted significant.

(Respectively, −10.3 ± 2.0% vs. −13 ± 3.1%, $P < 0.0001$).

In Figure 2, an ROC curve is used to identify the ability of the four segments SR summation and the 12 segments SR summation to predict total occlusion. The area under the ROC curve was 0.803 for the four middle segments SR summation and 0.759 for the 12 segments SR summation ($P = 0.0001$).

The sensitivity and specificity values of the SR in each middle segment in the four walls are shown in Figure 3. The highest sensitivity

TABLE III

LV Longitudinal Strain Rate Results of Total and Subtotal Occlusion Groups

Strain Rate (Per Seconds)	Total Occlusion Group (n: 35)	Subtotal Occlusion Group (n: 25)	P
Septum (%)			
Basal	−1.0 ± 0.4	−1.2 ± 0.3	0.1
Middle	−0.6 ± 0.2	−1.0 ± 0.3	<0.001
Apical	−0.4 ± 0.2	−0.6 ± 0.3	0.01
Lateral wall (%)			
Basal	−1.3 ± 0.3	−1.5 ± 0.3	0.1
Middle	−0.9 ± 0.3	−1.2 ± 0.3	<0.001
Apical	−0.4 ± 0.2	−0.7 ± 0.4	<0.001
Anterior wall (%)			
Basal	−1.3 ± 0.4	−1.3 ± 0.2	0.6
Middle	−0.7 ± 0.2	−0.9 ± 0.3	0.002
Apical	−0.3 ± 0.2	−0.5 ± 0.3	0.01
Inferior wall (%)			
Basal	−1.3 ± 0.3	−1.4 ± 0.3	0.4
Middle	−1.0 ± 0.3	−1.3 ± 0.3	0.001
Apical	−0.4 ± 0.3	−0.8 ± 0.3	<0.001
Anterior septum (%)			
Basal	−0.8 ± 0.2	−0.9 ± 0.2	0.01
Middle	−0.5 ± 0.2	−0.8 ± 0.2	<0.001

$P < 0.05$ accepted significant.

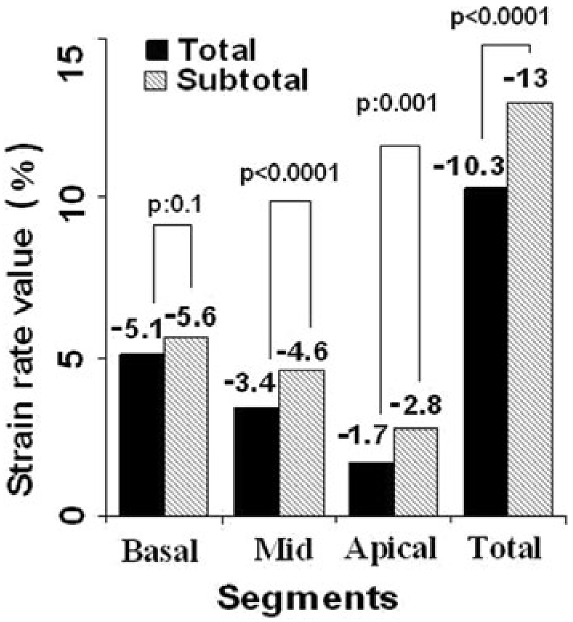

Figure 1. Total SR analysis of basal, mid and apical segments in two groups. SR values of middle, apical and all segments were significantly lower in total occlusion group.

levels (84%) were obtained in the middle-anterior wall (cutoff SR value: −0.71%). Middle-septum and middle-lateral walls have the highest specificity levels (cutoff SR value for the mid-septum: −1.02% and for middle-inferior wall: −1.2%).

Discussion:

In this study, we have assessed global and regional myocardial functions using S and SR echocardiography in patients who have total or subtotal occlusion in an infarct-related left anterior descending artery. Our results show that S and SR findings are significantly different in patients with total and subtotal occlusion. S and SR echocardiography may be used to detect or

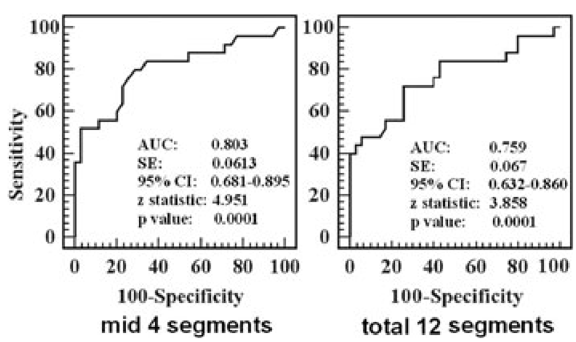

Figure 2. ROC curve of four middle and total 12 segments for presence of total occlusion. ROC curve analyses of segments. UAC = Under area curve; SE = Standard error, P-values were 0.0001 for middle four segment and total 12 segments.

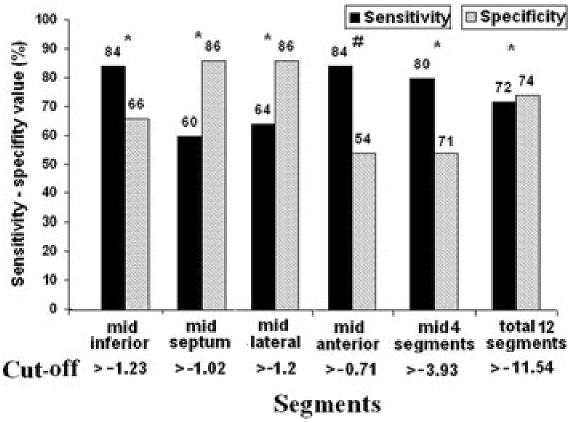

Figure 3. Sensitivity and specificity of SR values for total occlusion. Cutoff levels and their sensitivity and specificity values of each middle segment and totally SR value of middle segments. Middle inferior and anterior segments have highest sensitivity (84%). Highest specificity was obtained in middle lateral and middle septal segments. (%86) *P: 0.001 #P: 0.003.

predict the presence of total occlusion as a noninvasive and quantitative index.

The presence of total is one of the important determinative factors for the management of acute coronary syndrome. It was demonstrated that there is no clinical benefit of invasive approaches to total occlusion in stable patients with acute coronary syndrome irrespectively the baseline systolic functions.[2] Moreover, a trend toward excess reinfarction during 4 years of follow-up was observed in the invasive approach group. Based on these results, current guidelines do not recommend percutaneous coronary intervention for totally occluded infarct-related artery in asymptomatic patients who have hemodynamically and electrically stable clinical findings and who do not have evidence of severe ischemia.[12] Therefore, it is important to know the clinical and echocardiographic characteristics of patients with total occlusion.

In our study, the major finding is that patients who have total occlusion in an infarct related coronary artery have prominently decreased LV longitudinal S and SR values compared to patients with subtotal occlusion. The results of S and SR are varied in the basal, middle and apical segments. In patients with total occlusion, the most significant data was obtained when examining the SR of the middle four segments of septum, anterior, inferior and lateral walls. However, S values were similar in the basal segments in the two groups. These results were corroborated by a previous S echocardiography study.[13] The LV S values of the basal segments remained unchanged after acute left anterior descending artery occlusion.[13] The circumflex artery perfuses most of the lateral wall and the basal section of the anterior wall.[14] Also the basal sections of the septum, inferior and lateral walls are perfused by the dominant circumflex and right coronary arteries.[14] Thus, partial blood flow to the basal section of the LV may be supplied by the right coronary and circumflex arteries when total occlusion occurs in the left anterior descending artery. This situation may explain the unchanged S value in the basal segments after total occlusion in the left anterior descending artery. In an analysis of the SR of the basal section, only the SR of the anterior wall basal segment was significantly lower in patients with total occlusion. Relatively small differences between two groups were shown in SR findings of apical segments. Consequently, SR examination of the middle segments of the LV is most likely to yield prominent results in patients with total occlusion.

S and SR may provide valuable information about myocardial function and ischemia.[7,15,16] It was demonstrated that peak systolic SR value decrease with acute coronary occlusion.[17] In patients with acute occlusion of the coronary artery, S indexes differentiate acutely ischemic segments from both normal and dysfunctional myocardium.[18] The sensitivity and specificity values of systolic S parameters for ischemic myocardium were 86% and 83% in acute coronary occlusion.[18] In our study, SR values were significantly different in the case of total occlusion compared to partial occlusion. We also have analyzed the predictive ability of SR values of different segments. The SR values that most sensitively identified total occlusion were obtained on the middle anterior segment (84%) but the anterior wall has low specificity (54%). However, the SR values with the highest specificity were measured on the middle segments of the septum and lateral (86%). Taken together, our data show that the middle segment of the LV is the optimal place for SR measurement. Additionally, it can be concluded that the measurement of S and SR specific segments may be helpful for the identification of total occlusion in an infarct related left anterior descending artery.

Because of some technical challenges, single segment measurements may be insufficient in TDI derived S and SR echocardiography. Therefore, we have analyzed predictive role of total four and 12 segments. Sensitivity and specivity of these values were 80% and 71% for middle 4 segments. The sum of the SR of 12 segments has relatively moderate predictive values (sensitivity: 72% and specificity 74%). Beside of single segment, analyze of total segment also may be helpful for the identification of total occlusion in an infarct related left anterior descending artery.

Current guidelines suggest percutaneous coronary interventions to patients who have unstable conditions such as mechanical complications, cardiogenic shock, ongoing coronary ischemia and arrhythmia. However intervention to total occlusion in stable patients is not recommended. Main aim is to determine presence of total occlusion by S and SR echocardiography in stable patients in post MI period. Therefore, we have excluded unstable patients in post MI period. We suggest that the use of S and SR echocardiography to predict total occlusion will reduce the amount of unnecessary procedures performed in stable patients during the post-MI period.

Besides measuring and analyzing S and SR parameters, we have also assessed conventional echocardiography findings in patients with total occlusion. The LV ejection fraction was significantly lower in patients with total occlusion compared to patients without total occlusion (35.1 $\pm$ 8.6 vs. 43.0 $\pm$ 8.6, respectively). In addition, higher hs-CRP and higher diastolic blood pressure were measured in the total occlusion group.

Limitations:

S and SR derived by tissue Doppler technique is angle sensitive. This properties limit evaluation of some segment. Speckle tracking technique eliminates angle limitation. In our study, we have used tissue Doppler derived S and SR echocardiography. Speckle tracking might give more detailed and sensitive information in some segments.

Our hypothesis is that S and SR echocardiography may help to discriminate total occlusion in stable patients. However, in our study population, there were no additional clinical problems such as mechanical complications, ongoing coronary ischemia, arrhythmia and heart failure. Also, we excluded patients who had a significant lesion a coronary artery other than the left anterior descending artery. Current data suggest that early interventions should be performed in patients with unstable clinical conditions. Therefore, our study population was a very specific group. More complicated clinical findings and significant stenosis in the right or circumflex coronary artery may change S and SR values and utility. Therefore, the clinical implication of our study may be valid only in stable patients. We have investigated only patients who have anterior MI. The role of S and SR echocardiography is still uncertain in other patients.

Conclusion:

This S and SR echocardiography study shows that the presence of total occlusion in stable patients with ACS has an unfavorable effect on the LV regional and on global functions. Patients with total occlusion in an infarct related coronary artery may be identified by S and SR echocardiography. Such a distinction may facilitate appropriate clinical decisions and reduce unnecessary invasive procedures in stable patients.

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