Transthoracic ultrasonic tissue indices identify patients with severe left anterior descending artery stenosis. Correlation with fractional flow reserve. Pilot study

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Abstract

Background and aim: The aim of this study was to evaluate the potential clinical application of ultrasonic tissue indices, with a focus on systolic strain (SS) and systolic strain rate (SSR) parameters derived from transthoracic echocardiography, in the assessment of left anterior descending artery (LAD) stenosis.

Methods: The data of 30 patients with significant LAD stenosis were analysed. All patients underwent transthoracic echocardiography to obtain systolic myocardial velocity (Sm), longitudinal SS, and SSR from basal, mid, and apical segments of anterior and inferior walls in two-chamber apical view. Severity of LAD obstruction was measured by means of fractional flow reserve (FFR) during coronary catheterisation.

Results: Systolic velocities, strain, and strain rate measured in basal, middle, and apical segments of the anterior left ventricular (LV) wall were lower when compared to those obtained from the corresponding, i.e. unaffected, inferior LV wall. There was a significant correlation between FFR and the value of SS, SSR characterising the apical LV segment of the anterior wall (r = –0.583, p = 0.01; r = –0.598, p = 0.01, respectively). Moreover, we found significant correlation between FFR and Sm in the mid-segment of the LV anterior wall (r = 0.611, p = 0.009).

Conclusions: We conclude that SS and SSR obtained from the apical segment of the anterior LV wall may be related to the severity of LAD stenosis.

Key words: echocardiography, systolic strain, systolic strain rate, left anterior descending artery stenosis, coronary disease, fractional flow reserve

INTRODUCTION

In patients with coronary artery disease, evaluation of the functional significance of intermediate artery lesions remains a challenge. On the basis of pressure-derived analysis of stenosis during maximal coronary dilation, the concept of myocardial fractional flow reserve (FFR) has been developed as an invasively determined index of the functional severity of coronary stenosis [1, 2]. This index is widely accepted as the gold standard for the assessment of intermediate coronary artery narrowing [2, 3]. The noninvasive measurement of left anterior descending artery (LAD) stenosis by transthoracic echocardiography is feasible but it has some limitations [4]. Direct visualisation of coronary artery with the measurement of flow velocity remains difficult for everyone. Another approach could be dobutamine stress echocardiography applied both on
the basis of traditional qualification and quantitative assessment [5]. In the latter, deformation indices have been extensively used (strain, strain rate). So far, there have not been many studies on the relationship between selected tissue indices obtained from the anterior left ventricular (LV) wall and FFR results. Therefore, the aim of this study was to investigate potential clinical application of systolic strain (SS) and systolic strain rate (SSR) parameters, as well as other ultrasonic indices derived from rest transthoracic echocardiography, in the assessment of LAD stenosis in comparison to FFR results.

METHODS

Study population

A total of 30 patients with suspicion of significant, isolated (> 70% luminal narrowing) LAD stenosis by quantitative coronary angiography and computed tomography angiography underwent transthoracic echocardiography and FFR study. Exclusion criteria were history of myocardial infarction, unstable angina, congestive heart failure, persistent atrial or ventricular arrhythmia, uncontrolled hypertension, atrioventricular block, atrial fibrillation, more than mild valvular heart disease, or LV ejection fraction (LVEF) less than 35% and obstructive pulmonary disease. All patients were in stable sinus rhythm and had normal resting LV function. The study protocol conformed to the ethical guidelines of the 1975 Declaration of Helsinki. It was approved by the local Research Ethics Committee. Written informed consent was also obtained from each patient.

Standard echocardiography

All patients underwent a complete transthoracic echocardiographic study with the use of GE Medical System Vivid 7 (GE Healthcare) and with a 2.5-MHz transducer. M-mode, two-dimensional, tissue Doppler echocardiography were obtained by imaging in parasternal long and short axes and in apical four-, three-, and two-chamber views. The left ventricle was divided according to the 16-segment model of the American Society of Echocardiography [6]. The values of all echocardiographic parameters were obtained as the average of three consecutive cardiac cycles. LV end-systolic and LV end-diastolic diameters, as well as interventricular septal diastolic diameter and posterior LV wall diastolic diameter, were measured using the M-mode technique. LV systolic function was evaluated by LVEF, mitral lateral annular systolic velocity wave (S’LV), and LV outflow tract velocity-time integral. LVEF was calculated using the biplane Simpson formula. S’LV was measured using Doppler tissue imaging placed sample volume in the basal segment of the LV lateral wall in a four-chamber view. All parameters were recorded in accordance with current guidelines [7].

Strain and strain rate imaging

After performing conventional echocardiography, strain rate images were obtained with commercially available echocardiography equipment GE Medical System Vivid 7 (GE Healthcare). Apical four-, three-, and two-chamber colour Doppler tissue imaging were taken at a high frame rate (150–200 fps) and analysed using Echo Pac 3.0 (GE Medical System). The region of interest was placed at basal, mid, and apical segments of LV anterior and inferior walls. To determine longitudinal strain and strain rates, data were averaged from three consecutive cardiac beats at each site. An offset to measure strain and strain rate was set at 9–11 mm. Manual tracking throughout the cardiac cycle was used for all the patients. Aortic valve closure was preserved as a marker for end systole. SS was defined as the magnitude of the deformation measured from end diastole to end systole. SSR described the maximum rate of deformation during systole.

Fractional flow reserve assessment

Fractional flow reserve was calculated as the ratio of mean distal coronary pressure to the mean aortic pressure at rest and during maximal hyperaemia. FFR measurement was performed with a 0.014-inch pressure wire (RADI Medical systems, Uppsala, Sweden, or PressureWire® Aeris, St. Jude Medical) advanced via a 6 Fr guiding catheter distal to the target coronary lesion. To achieve the maximal hyperaemia, continuous adenosine infusion (140 μg/min/kg) via a forearm vein was administered up to 3 min. FFR value ≤ 0.8 was considered functionally significant.

Statistical analysis

Collected data are presented as mean ± standard deviation, and frequency is presented as percentage. Student’s t-test was used to compare the mean differences between basal, mid, and apical segments of inferior wall variables and anterior LV wall strain, rate, and velocities. Pearson’s correlation was used to investigate the correlation of variables. Parameters identified as statistically significant based on univariate analysis (p < 0.05) were included in the multivariable linear regression model to determine the combined effect of several variables on the prevalence of the characteristics. P < 0.05 was considered statistically significant. All statistical analyses were performed using the commercially available computer software PASW Statistics 18 (SPSS, Chicago, IL).

RESULTS

The data sets of 30 patients were obtained and analysed. The mean age of the study subjects was 62.6 ± 7.5 years (range 60.1–65.1 years; 21 males and 9 females). Mean heart rate was 65 ± 11 bpm. LVEF was above 50% in all cases, and mean LVEF amounted to 54.5 ± 8.0%. The baseline echocardiographic characteristics of the patients are shown
Mean FFR value was 0.78 ± 0.13. In 15 (50%) patients FFR was less than 0.8.

Systolic velocity, SS, and SSR measured in basal, mid, and apical segments of the anterior LV wall were lower when compared to those obtained from the corresponding, i.e. unaffected, inferior LV wall in all patients (Table 2).

There was a significant correlation between FFR and the value of SS and SSR obtained only from the apical segment of the anterior LV wall (r = −0.583, p = 0.01; r = −0.598, p = 0.01, respectively). Moreover, we found a significant correlation between FFR and systolic myocardial velocity (Sm) in the mid segment of the anterior LV wall (r = 0.611, p = 0.009).

To evaluate independent factors related to FFR value, a linear regression model was performed. The factor independently associated with FFR was only SSR measured in the apical segment of the anterior wall (Table 3).

**DISCUSSION**

In some patients the appropriate assessment of the severity of coronary artery stenosis continues to be a challenge for cardiologists. The quantification of coronary artery lesion does not describe the amount of ischaemia in the relevant territory. A number of methods can give an insight into regional myocardial performance. One of these is echocardiography, which is widely available and cheap but yet subjective [8].
Ultrasonic strain and strain rate can help to overcome the subjectivity of the method [9, 10]. In the recent years, these techniques have been extensively used to differentiate clinically significant coronary stenosis [11–13]. Ultrasonic strain and strain rate are, in theory, independent of the overall heart motion and can be reliably used to measure regional myocardial deformation and deformation rate [10, 14]. It is known that Sm, SS, and SSR are different in particular walls of LV. In the HUNT study, which investigated the distribution of longitudinal strain and strain rate in a healthy population of 1296 subjects, the authors did not find statistically important differences between basal, mid, and apical segments of anterior and inferior wall [15]. In the presented study, we evaluated patients with LAD stenosis confirmed in computed tomography or coronary catheterisation. We found that Sm, SS, and SSR measured in basal, mid, and apical segments of the anterior LV wall were lower when compared to those obtained from the corresponding, i.e. unaffected, inferior LV wall. Ojaghi-Haghighi et al. [16] evaluated 14 patients with severe LAD stenosis, who underwent successful selective percutaneous coronary intervention (PCI). In this study the referenced myocardial deformation indices (SS and SSR) were recorded before and after PCI, both at rest and during stress echo test. The authors showed differences in SS and SSR in resting condition and during stress test echocardiography before and after PCI of LAD [16]. Edvardsen et al. [17] evaluated whether strain rate imaging could detect acute myocardial ischaemia, and compared the method with tissue Doppler imaging during acute coronary ischaemia. They examined patients undergoing angioplasty of the LAD, and they assessed LV longitudinal wall motion by tissue velocities and strain obtained from the apical four-chamber view. They concluded that the strain rate imaging detected longitudinal dyskinesia during occlusion of the LAD more frequently than the tissue Doppler velocity. Weidemann et al. [18] evaluated patients with acute ST elevation myocardial infarction and found that before and after PCI both strain and strain rate were markedly reduced in the ischaemic segments as compared with the non-ischaemic remote regions [18].

Fractional flow reserve is defined as the ratio of maximum blood flow in a stenotic coronary artery in reference to normal maximum flow in the same vessel [19]. In contrast to other invasive indices, FFR has a direct clinical relevance for determining critical coronary stenosis, which causes myocardial ischaemia [20]. Compared to other invasive indices, FFR is not dependent on changes in heart rate, blood pressure, or contractility. An approved correlation between FFR and tissue echocardiographic parameters would make transthoracic echo scan a clinically useful tool for diagnosis of the severity of coronary artery disease. Dagdelean et al. [21] enrolled in their study 17 patients, and FFR was studied in 22 vessels, in which 10 lesions were found to be critically important. There were no differences in Sm, SSR, and SS values between critical or noncritical FFR groups in resting condition. Baseline Sm value and change between baseline and peak Sm and SS during stress echocardiography were significantly lower in the noncritical FFR group (p < 0.01, p < 0.001, p < 0.001, respectively). The authors found mild correlation between FFR and SSR (r = 0.47, p = 0.044) and good correlation with SS (r = 0.66, p = 0.002). The authors concluded that quantification of regional myocardial deformation by using stress echocardiography rather than the motion would be more appropriate in detecting the ischaemic dysfunctional segment supplied by the vessel with critical stenosis. Strain measurement during the dobutamine infusion could then provide information on the FFR results of the culprit vessel.

To the best of our knowledge, there are no studies to investigate the direct correlation between FFR measurement and strain and strain rate parameters obtained from the territory of the LV segment supplied by the relevant vessel in resting echocardiography. In the presented study statistically significant differences were observed in systolic velocities, strain, and strain rate between the anterior and inferior wall. We also found a correlation between FFR results and SS and SSR obtained from the apical segment of the LV anterior wall (r = −0.583, p = 0.01; r = −0.598, p = 0.01, respectively). We managed to document that tissue velocity, SS, and SSR might be promising for the differentiation between the ischaemic myocardial segment and the non-ischaemic during resting echocardiography as compared to the severity of the supplying artery, i.e. LAD.

CONCLUSIONS

Systolic strain rate measured in the apical segment of the anterior wall may be related to the severity of LAD stenosis in resting echocardiography. These data might be implemented in a clinical setting. It should be underlined that the described method is completely non-invasive. This study may help to predict the functional improvement of the myocardial wall before revascularisation.

Future studies including a larger study population and more selective cases will be needed to show the accuracy of SSR imaging results in resting condition when compared with FFR values.

Conflict of interest: none declared

References


Zastosowanie tkankowej echokardiografii przeklktkowej do identyfikacji pacjentów z ciasnym zwężeniem gałęzi przedniej zstępującej. Korelacja parametrów odkształcenia podłużnego z wynikami cząstkowej oceny przepływu wieńcowego. Badanie pilotażowe

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Streszczenie

Wstęp i cel: Celem niniejszej pracy była ocena przydatności klinicznej parametrów maksymalnego odkształcenia podłużnego (SS) i tempa odkształcenia podłużnego (SSR) uzyskanych w przeklktkowym badaniu echokardiograficznym w określeniu stopnia zwężenia gałęzi przedniej zstępującej lewej tętnicy wieńcowej.

Metody: Analizie poddano 30 pacjentów z istotnym zwężeniem gałęzi przedniej zstępującej. U wszystkich wykonano przeklktkowe badanie echokardiograficzne, na podstawie którego oceniono prędkość skurczową (Sm), podłużne SS i SSR z segmentu podstawnego, środkowego i koniuszkowego ściany przedniej i dolnej. Stopień zwężenia gałęzi przedniej zstępującej był oceniany za pomocą pomiaru cząstkowej rezerwy przepływu (FFR).

Wyniki: Wszystkie wartości prędkości miokardialnych, SS i SSR oceniane z podstawnego, środkowego i koniuszkowego segmentu ściany przedniej były niższe w porównaniu z odpowiednimi wartościami uzyskanymi z segmentów nieobjętych niedokrwieniem ściany dolnej. Uzyskano istotne statystycznie korelacje wartości FFR z wartościami SS, SSR dla segmentu koniuszkowego ściany przedniej (odpowiednio: \( r = -0,583; p = 0,01 \); \( r = -0,598; p = 0,01 \)). Ponadto stwierdzono korelację między FFR i wartością Sm dla segmentu środkowego ściany przedniej (\( r = 0,611; p = 0,009 \)).

Wnioski: Spoczynkowe wartości SS i SSR uzyskane z koniuszkowego segmentu ściany przedniej mogą odzwierciedlać istotność zwężenia gałęzi przedniej zstępującej lewej tętnicy wieńcowej.

Słowa kluczowe: echokardiografia, skurczowe odkształcenie podłużne (strain), tempo odkształcenia podłużnego, zwężenie gałęzi przedniej zstępującej, choroba wieńcowa, cząstkowa rezerwa przepływu