

Two-dimensional longitudinal strain for the assessment of the left ventricular systolic function as compared with conventional echocardiographic methods in patients with acute coronary syndromes

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Abstract

Background: The evaluation of the left ventricular (LV) function is one of the most important elements of diagnosis in patients with cardiovascular (CV) diseases. A low LV ejection fraction (LVEF) is a strong and independent predictor of CV events. Traditionally, echocardiography characterises the LV systolic function by the estimation of LVEF with use of the Simpson method, supported by the wall motion score index (WMSI). Speckle tracking imaging is a new method of LV function imaging based on the estimation of longitudinal peak systolic strain (LPSS), by tracing of the automatically detected myocardial speckles.

Aim: To evaluate the usefulness of global longitudinal peak systolic strain (GLPSS) and regional longitudinal peak systolic strain (r-LPSS) in LV systolic function assessment and to compare LPSS with conventional parameters such as LVEF, WMSI and regional wall motion score index (r-WMSI).

Methods: The study was performed in a group of 44 patients with a clinical diagnosis of acute coronary syndrome (mean age 63.6 ± 12.2 years). The LVEF, WMSI, r-WMSI were estimated by echocardiography (VIVID 7 Dimension, GE Healthcare, USA). Moreover, LPSS (GLPSS and r-LPSS) with use of automated function imaging (AFI) were also estimated.

Results: In the study group mean LVEF was $43.1 \pm 12.7\%$, mean WMSI: 1.68 ± 0.52 , and GLPSS: $-13.8 \pm 5.6\%$. A very strong linear correlation between the conventional and new parameters was observed — for GLPSS and LVEF: $r = -0.86$ ($p < 0.00001$), for GLPSS and WMSI: $r = 0.88$ ($p < 0.00001$). The results of the regional myocardial contractility assessment (r-LPSS and r-WMSI) were also in agreement, especially for LV anterior wall ($r = 0.87$, $p < 0.00001$).

Conclusions: These results suggest a considerable usefulness of LPSS — a new method of echocardiographical imaging — in the estimation of global and regional LV function in patients with acute coronary syndrome and its agreement with conventional parameters such as LVEF and WMSI.

Key words: left ventricular systolic function, 2D strain imaging, echocardiography, acute coronary syndrome

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INTRODUCTION

Left ventricular (LV) systolic function assessment is an important part of the diagnostic workup of patients with cardiovascular (CV) diseases, and LV ejection fraction (LVEF) is a strong,

independent prognostic factor, used for patient allocation to specific management strategies (e.g. cardioverter-defibrillator implantation). Traditionally, echocardiographic measurement of LVEF is performed with the Simpson method. Regional

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systolic function assessment is more challenging, as it is based on subjective visual assessment of concentric movement and thickening of individual myocardial segments. To make the assessment of individual segment contractility more objective, a semi-quantitative score was developed, for which the averaged score value for all segments corresponds to wall motion score index (WMSI).

Left ventricular systolic strain measurement (2D strain), based on an algorithm of acoustic marker (pixel) tracking of standard 2D images (speckle tracking echocardiography) is a new echocardiographic technique for LV systolic function assessment [1]. The results of the studies published to date point to significant correlation of the longitudinal strain (LPSS — longitudinal peak systolic strain) with LVEF. However, the strength of this correlation in various clinical settings has not been unequivocally determined [2, 3].

The aim of this study was to determine the agreement between global contractility assessment by LPSS and by LVEF and between global and regional contractility and WMSI.

METHODS

Study population

Forty four consecutive patients, aged 63.6 ± 12.2 (10 females), referred to our centre with suspected acute coronary syndrome (ACS) and undergoing echocardiographic assessment (VIVID 7 Dimension, GE Healthcare, USA), were included in the study. In all the patients, echocardiographic images were obtained, allowing for visual analysis of all LV segments and automatic speckle tracking of good quality. Seven patients not meeting these criteria were excluded from the study groups.

Echocardiographic assessment

The study protocol included standard assessment in parasternal and apical views, including LVEF evaluation with the Simpson method, calculated from images obtained in the apical four-chamber and two-chamber views. Sixteen-segment LV model was adopted, in which individual segment contractility was scored according to standard criteria (1 — normokinesia, 2 — hypokinesia, 3 — akinesia, 4 — dyskinesia). The WMSI was calculated as an arithmetic mean score of all the LV segments. Additionally, regional WMSI (r-WMSI) was calculated, according to analogous arithmetic rule.

For the assessment of LV longitudinal strain, dedicated automated function imaging (AFI) protocol was used. Digital images acquired in the apical long axis (APLAX), apical two-chamber (A2C) and apical four-chamber (A4C), loop-recorded with ECG gating, were analysed. As required, high temporal resolution of > 50 frames per second was obtained, in order to enable acoustic myocardial marker tracing. The detection of tracked area was carried out semi-automatically after selection of two basal points at the level of mitral annulus and the third point in the apex, with optional manual correction. In each of the apical views, LV walls were divided into six segments, for each LV segment the value of strain and

quality of tracing were then assessed. For each of the three views, mean LPSS value was calculated (G APLAX, G A2C, G A4C). The value of the global longitudinal LV strain index was calculated as the arithmetical mean of these values (GLPSS — global longitudinal peak systolic strain). For the study purpose, averaged regional strain values for the individual LV walls were also calculated (r-LPSS — regional LPSS).

Statistical analysis

The results were analysed with use of Statistica 7.0 statistical package (StatSoft Inc.). Data distribution was assessed visually and with Shapiro-Wilk test. The results are presented as mean \pm SD for continuous variables and as numbers and percentages for categorical variables. Correlations between selected variables were verified by Pearson correlation coefficient (for normal data distribution) and Spearman coefficient (for non-normal data distribution). A p value < 0.05 was considered significant.

RESULTS

After detailed clinical and laboratory workup of the group of 44 patients with suspected ACS, acute myocardial infarction was diagnosed in 36 (80%) patients, and unstable angina in 5 (13%). In the remaining 3 patients, the diagnosis of an ACS was not confirmed (in 2 patients dilated cardiomyopathy, and in 1 patient pulmonary embolism were diagnosed). All the patients underwent coronary angiography and 36 underwent angioplasty in the acute phase. Final analysis included data from 41 patients in whom ACS was diagnosed. Clinical characteristics of the study population are summarised in Table 1.

Mean values of the echocardiographic parameters were as follows: LVEF = $43.1 \pm 12.7\%$, WMSI = 1.68 ± 0.52 , GLPSS = $-13.8 \pm 5.6\%$. Mean r-LPSS and r-WMSI values calculated for individual LV walls are presented in Table 2.

A strong significant linear correlation was found between parameters of global systolic LV function: GLPSS and LVEF as well as GLPSS and WMSI (Table 3, Fig. 1). Average strain correlation analysis confirmed significant LPSS relationship with LVEF and WMSI. The strongest correlation was found

Table 1. Clinical characteristics of the study population (n = 41)

Age [years]	63.6 \pm 11.7
Male	32 (78.0%)
Smoking	19 (46.3%)
Hypertension	29 (70.7%)
Hyperlipidaemia	26 (63.4%)
Diabetes	12 (29.2%)
Acute myocardial infarction	36 (87.8%)
History of myocardial infarction	14 (34.1%)
Unstable coronary artery disease	5 (12.2%)
Acute phase revascularisation	34 (82.3%)

Table 2. The values of r-LPSS and r-WMSI for individual left ventricular walls

	r-WMSI	r-LPSS (%)
Interventricular septum	1.71 ± 0.75	-11.3 ± 8.7
Lateral wall	1.54 ± 0.66	-12.5 ± 8.3
Inferior wall	1.78 ± 0.70	-12.7 ± 7.6
Anterior wall	1.67 ± 0.77	-12.7 ± 8.4
Infero-septal wall	1.64 ± 0.61	-13.4 ± 6.5
Antero-septal wall	1.77 ± 0.78	-11.6 ± 10.3

r-LPSS — regional longitudinal peak systolic strain; r-WMSI — regional wall motion score index

Table 4. Correlations between r-WMSI and r-LPSS for individual left ventricular walls

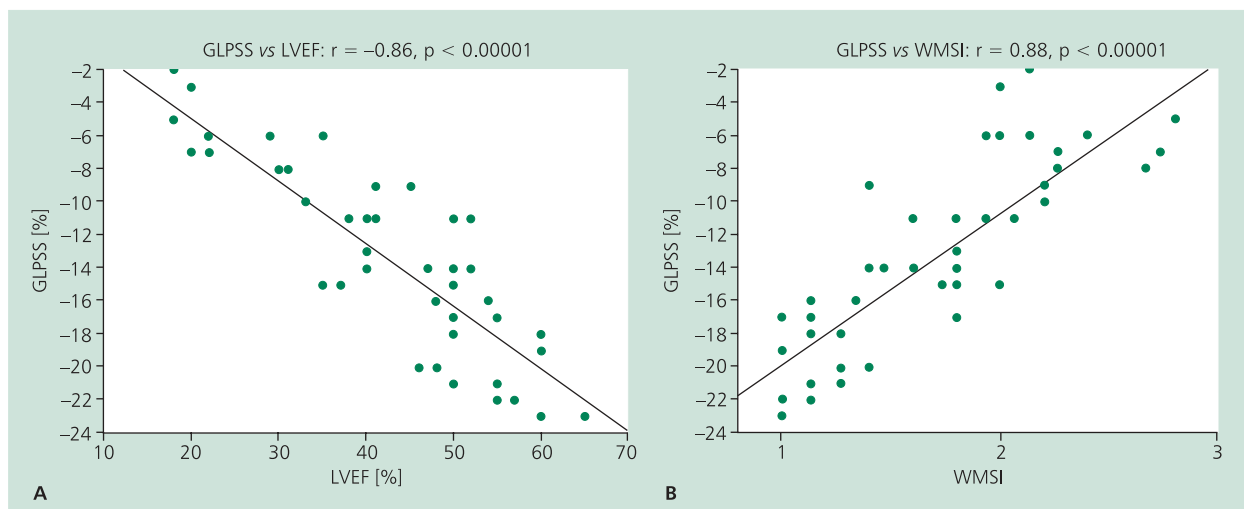
	r-LPSS vs r-WMSI	
	r	P
Interventricular septum	0.82	< 0.00001
Lateral wall	0.68	< 0.00001
Inferior wall	0.67	< 0.00001
Anterior wall	0.87	< 0.00001
Infero-septal wall	0.63	< 0.00001
Antero-septal wall	0.78	< 0.00001

Abbreviation as in Table 1

Table 3. Correlations between LPSS and LVEF and WMSI

	LVEF		WMSI	
	r	P	r	P
GLPSS	-0.86	< 0.00001	0.88	< 0.00001
G APLAX*	-0.84	< 0.00001	0.83	< 0.00001
G A4C*	-0.77	< 0.00001	0.82	< 0.00001
G A2C*	-0.90	< 0.00001	0.89	< 0.00001

*Mean longitudinal peak systolic strain (LPSS) value for the following views: long axis (G APLAX), apical four-chamber (G A4C) and apical two-chamber (G A2C); GLPSS — global longitudinal peak systolic strain; LVEF — left ventricular ejection fraction; WMSI — wall motion score index

**Figure 1.** Correlation of global longitudinal peak systolic strain (GLPSS) versus left ventricular ejection fraction (LVEF) (A) and wall motion score index (WMSI) (B)

for G A2C, whereas the weakest, but still quite high, for G A4C (Table 3). Similarly, the regional systolic function parameters, i.e. r-WMSI and r-LPSS, calculated for individual LV walls, showed strong correlation; the highest for the anterior wall and the lowest, albeit still quite strong for the infero-septal wall (Table 4).

DISCUSSION

Left ventricular ejection fraction is one of the most extensively studied and the strongest prognostic factors in patients with coronary artery disease, chronic heart failure and other CV disorders [4]. Based on large clinical trials, evaluating a number of therapeutic strategies, LVEF value was also approved

as a parameter that warrants specific management strategy. However, LVEF is not a simple measure of LV systolic performance — it is also influenced by LV volume, preload, afterload, valvular function [5], or regional hyperkinesis after myocardial infarction [6]. Additionally, the reproducibility of the measurement method is not always satisfactory.

The parameter of higher sensitivity in the assessment of regional systolic dysfunction is WMSI. According to some authors, it is also a more powerful prognostic factor than LVEF [7]. A limitation of WMSI measurement is related to subjective and semi-quantitative method of regional systolic function, which requires high expertise of the observer, high image quality and can result in overlooking of small areas of dysfunctional myocardium.

The new method of myocardial systolic function assessment, i.e. 2D longitudinal strain measurement, based on acoustic marker tracing technique, seems potentially devoid of limitations adherent to conventional methods. Due to its objectiveness, the important factor of intra-observer variability is eliminated, and this results in good reproducibility of the method, as reported by a number of authors [8, 9]. The quantitative nature of strain may allow for evaluation of the full spectrum of systolic dysfunction, from normal to unequivocally impaired systolic function. Thus, the decreased LPSS value carries additional information in the setting of myocardial injury indiscernible by conventional echocardiographic assessment of LV systolic function. Results of a number of studies suggest that the GLPSS value may be decreased in a population of heart failure patients with preserved LVEF [10], in patients with 3-vessel coronary artery disease and left main disease without regional wall motion abnormalities on resting echocardiography [11] and during therapeutic safety monitoring in patients treated with cardiotoxic chemotherapeutics [12, 13].

Our results suggest that longitudinal LV strain measurement based on acoustic marker tracking credibly reflects the global as well as regional LV systolic function as compared with standard echocardiographic assessment. In our study, significant convergence of GLPSS measurements with LVEF and WMSI was found. These results are in agreement with those of other authors [2, 8, 14]. It should be noted, however, than in the study by Delgado et al. [3], in a subgroup of patients with acute myocardial infarction (STEMI), the correlation of GLPSS with LVEF was weaker ($r = 0.42$).

The comparison of mean regional strain (r-LPSS) and regional contractility indices (r-WMSI) for individual LV walls is a continuation of earlier observations concerning GLPSS. High agreement was demonstrated between the respective r-LPSS and r-WMSI measurements, which renders regional strain assessment a credible tool for identification of regional systolic function abnormalities. The differences in the correlation coefficient values can result from variable level of difficulty in contractility assessment of individual walls and in specific

views. However, the potential value of LPSS as a method of clarification of uncertainties related to the standard examination needs further study.

When comparing LVEF and GLPSS, it should be kept in mind that these are not identical, interchangeable parameters, but that they describe different components of LV systolic function. The LVEF is a derivative of volume change, dependent on haemodynamic status, such as volaemia, preload and afterload, as well as on myocardial contractility including circumferential and subendocardial fibers. Similarly, the function of mid-wall fiber layer and, to a lesser extent, the subendocardial layer of myocardium translates to WMSI value. The GLPSS in turn reflects directly the function of longitudinal myocardial fibers, the strain of which is closely related to subendocardial layer contraction.

Autopsy studies demonstrated that the subendocardial layer is the most prone to ischaemic injury [15], and in an experimental model the contractility of longitudinal fibers becomes impaired earlier and more easily than the circumferential fiber function [16]. In this context, the LPSS assessment in the population of patients with ACS and the resulting opportunity to compare the measurements with standard LV function assessment become particularly valuable. It is the assessment of various aspects of LV contractility that can explain the results obtained by Stanton et al. [17] in a relatively large but non-homogenous group of 546 patients with mean LVEF of $58 \pm 12\%$ and with mean observation period of 5.2 years. The authors found higher predictive value of LPSS for overall mortality in comparison with LVEF and WMSI.

It should be kept in mind, however, that significant limitations of the LPSS method include: (1) lack of defined reference values, despite attempts to define them in clinical trials [9, 18]; (2) need for obtaining high image quality and (3) little availability and high cost of the AFI software.

Limitations of the study

The limitation of our study was the lack of homogeneity of the study group and low number of participants. However, the aim of the study was not the verification of the potential discrepancies between methods of LV contractility assessment, as there was no reference method involved, such as magnetic resonance imaging, allowing for highly objective reference examinations. This made impossible defining of a cut-off point for LPSS values. Similarly, the intra-observer and inter-observer variability indices were not measured (chiefly due to the clinical status of the patients, which warranted prompt therapeutic intervention).

It should be expected, however, that the automatic measurement by the LPSS method can in some cases be easier and more precise than the assessment with conventional methods. It seems that this method can become a tool for patient monitoring in clinical settings such as unstable angi-

na, heart failure with preserved LVEF or cardiotoxic chemotherapy, in which myocardial injury is imminent. Its validation, however, needs further study of large patient groups.

CONCLUSIONS

Our results demonstrate substantial agreement between longitudinal strain measurement in 2D imaging and standard parameters of the global and regional LV contractility with established clinical value in the assessment of patients with ACS. These results encourage further research on the usefulness of the method in myocardial contractility imaging in various clinical settings.

Conflict of interest: none declared

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Odształcenie podłużne obrazu dwuwymiarowego w ocenie funkcji skurczowej lewej komory u pacjentów z ostrymi zespołami wieńcowymi w porównaniu z klasycznymi metodami echokardiograficznymi

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Streszczenie

Wstęp: Ocena czynności skurczowej lewej komory (LV) jest ważnym elementem procesu diagnostycznego u pacjentów z chorobami sercowo-naczyniowymi, a wartość frakcji wyrzutowej lewej komory (LVEF) stanowi silny, niezależny czynnik prognostyczny. Tradycyjnie LVEF w echokardiografii mierzy się najczęściej za pomocą metody Simpsona, a w celu poprawy obiektywizacji oceny kurczliwości poszczególnych segmentów stosuje się półilościową skalę punktową, dla której uśredniona wartość punktacji dla wszystkich segmentów odpowiada wskaźnikowi kurczliwości lewej komory (WMSI). Nową techniką echokardiograficzną odzwierciedlającą czynność skurczową LV jest pomiar jej odkształcenia dwuwymiarowego (*strain 2d*) oparty na algorytmie śledzenia markerów akustycznych (*speckle tracking imaging*) podstawowego obrazu dwuwymiarowego. Wyniki dotychczas przeprowadzonych badań wskazują na istotną korelację odkształcenia podłużnego (LPSS) z LVEF, choć siła tego związku w różnych stanach klinicznych nie została jednoznacznie rozstrzygnięta

Cel: Celem pracy była ocena wartości techniki echokardiograficznej pomiaru globalnego odkształcenia podłużnego (GLPSS) i regionalnego (r-LPSS) w ocenie funkcji skurczowej LV u chorych z rozpoznaniem ostrego zespołu wieńcowego (OZW) oraz jej porównanie z parametrami klasycznymi, takimi jak LVEF, WMSI i regionalne WMSI (r-WMSI).

Metody: Badanie przeprowadzono w grupie 44 pacjentów w średnim wieku $63,6 \pm 12,2$ roku (10 kobiet), kierowanych do ośrodka autorów z powodu podejrzenia i/lub rozpoznania OZW. Ostatecznej analizie poddano grupę 41 chorych z potwierdzonym rozpoznaniem OZW. W ocenie echokardiograficznej uwzględniono: LVEF, WMSI i r-WMSI dla każdej ze ścian LV. Oceny LPSS dokonano metodą śledzenia punktu akustycznego obrazów dwuwymiarowych (*strain 2d*), z wykorzystaniem dedykowanego algorytmu AFI (*automated function imaging*, aparat GE Vivid 7). Dla każdej z trzech projekcji obliczono wartość średnią odkształcenia podłużnego (G APLAX, G A2C, G A4C). Wartość GLPSS wyliczono jako średnią arytmetyczną tych wartości. Dla potrzeb badania określono również wartości średnie odkształceń dla poszczególnych ścian LV (r-LPSS).

Wyniki: W badanej grupie średnia LVEF wynosiła $43,1 \pm 12,7\%$, WMSI $1,68 \pm 0,52$, a GLPSS $-13,8 \pm 5,6\%$. Stwierdzono wysoką, istotną statystycznie korelację liniową między parametrami oceniającymi globalną funkcję skurczową LV: GLPSS i LVEF ($r = -0,86$; $p < 0,00001$) oraz GLPSS i WMSI ($r = 0,88$; $p < 0,00001$). Analiza korelacji średniego odkształcenia dla różnych projekcji koniuszkowych (G APLAX, G A4C, G A2C) potwierdziła istotną zależność LPSS z LVEF i WMSI, najwyższą dla G A2C. Parametry regionalnej oceny kurczliwości miokardium (r-LPSS i r-WMSI) wykazywały wysokie i bardzo wysokie korelacje, najwyższą dla ściany przedniej ($r = 0,87$; $p < 0,00001$), a najniższą, choć nadal wysoką, dla ściany dolno-podstawnej ($r = 0,63$; $p < 0,00001$).

Wnioski: Przedstawione wyniki wskazują na istotną zgodność pomiaru podłużnego odkształcenia w prezentacji dwuwymiarowej z parametrami o powszechnie uznanej wartości klinicznej w ocenie globalnej i odcinkowej kurczliwości LV w populacji pacjentów z OZW.

Słowa kluczowe: funkcja skurczowa lewej komory, odkształcenie dwuwymiarowe, echokardiografia, ostry zespół wieńcowy

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