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The usefulness of the left ventricle myocardial performance index (LV MPI) to assess left ventricular function in children with myocarditis

Przydatność wskaźnika sprawności mięśnia sercowego (LV MPI) do oceny funkcji lewej komory serca u dzieci z zapaleniem mięśnia sercowego

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Abstract

Introduction and objective: Myocarditis, due to its diverse clinical presentation, is a big challenge for clinicians. Aim of the paper was to assess the left ventricular myocardial performance index by echocardiography and the relationship between left ventricular myocardial performance index and the oedema in T2-weighted cardiac magnetic resonance imaging in children with myocarditis. **Materials and methods:** The retrospective study included 32 patients with diagnosed myocarditis, in whom echocardiographic parameters, including left ventricular myocardial performance index, were compared with cardiac magnetic resonance imaging results. The control group consisted of 30 teenagers. **Results:** Statistically significant differences were obtained between the mean values of the left ventricle myocardial performance index in the study group compared to the values in the control group for the basal segment of the interventricular septum, respectively 0.52 ± 0.07 vs. 0.4 ± 0.08 ($p < 0.001$), the basal segment of the lateral wall 0.48 ± 0.02 vs. 0.41 ± 0.08 ($p = 0.019$) and the middle segment of the interventricular septum 0.5 ± 0.01 vs. 0.39 ± 0.09 ($p = 0.001$). In 12 patients the average value of the left ventricle myocardial performance index was <0.5, in 8 of them (66.6%), no residual changes were observed on cardiac magnetic resonance after 9 ± 2 months. All patients in whom average left ventricle myocardial performance index was >0.5, residual changes persisted in cardiac magnetic resonance. **Conclusions:** In children with myocarditis, the values of the left ventricle myocardial performance index in echocardiography are increased. Higher values of left ventricle myocardial performance index indicate a longer duration of the inflammatory process, which is reflected in cardiac magnetic resonance imaging.

Keywords: myocarditis, left ventricle myocardial performance index, cardiac magnetic resonance imaging

Streszczenie

Wprowadzenie i cel: Zapalenie mięśnia sercowego z uwagi na różnorodny obraz kliniczny stanowi duże wyzwanie dla lekarzy. Celem pracy była echokardiograficzna ocena wskaźnika funkcji lewej komory i zbadanie zależności między wartościami wskaźnika funkcji lewej komory a występowaniem obrzęku w obrazowaniu T2-zależnym w rezonansie magnetycznym serca u dzieci z zapaleniem mięśnia sercowego. **Materiał i metody:** Badaniem retrospektywnym objęto 32 pacjentów z rozpoznanym zapaleniem mięśnia sercowego, u których przeanalizowano parametry echokardiograficzne, w tym wskaźnik funkcji lewej komory, i porównano z obrazem rezonansu magnetycznego serca. Grupę kontrolną stanowiło 30 nastolatków. **Wyniki:** Uzyskano istotne statystycznie różnice między średnimi wartościami wskaźnika funkcji lewej komory w grupie badanej a wartościami uzyskanymi w grupie kontrolnej dla segmentu podstawnego przegrody międzykomorowej, odpowiednio 0,52 ± 0,07 *vs* 0,4 ± 0,08 ($p < 0,001$), dla segmentu podstawnego ściany bocznej 0,48 ± 0,02 *vs* 0,41 ± 0,08 ($p = 0,019$) oraz dla segmentu środkowego przegrody międzykomorowej 0,5 ± 0,01 *vs* 0,39 ± 0,09 ($p = 0,001$). U 12 pacjentów z grupy badanej uśredniona wartość wskaźnika funkcji lewej komory wyniosła <0,5, u 8 (66,6%) z nich nie stwierdzono zmian rezydualnych pod postacią śródmiąższowych lub podnasierdziowych obszarów późnego wzmocnienia kontrastowego w kontrolnym rezonansie magnetycznym serca po 9 ± 2 miesiące. U wszystkich pacjentów z zapaleniem mięśnia sercowego, u których wskaźnik funkcji lewej komory wynosił średnio >0,5, utrzymywały się natomiast zmiany

w kontrolnym rezonansie magnetycznym serca wykonanym w odstępie 9 ± 2 miesiące. **Wnioski:** U dzieci z zapaleniem mięśnia sercowego wartości wskaźnika funkcji lewej komory serca w badaniu echokardiograficznym są podwyższone. Wyższe wartości wskaźnika funkcji lewej komory serca świadczą o dłuższym czasie trwania procesu zapalnego, co znajduje odzwierciedlenie w badaniach rezonansem magnetycznym serca.

Słowa kluczowe: zapalenie mięśnia sercowego, wskaźnik funkcji lewej komory serca, rezonans magnetyczny serca

INTRODUCTION

Myocarditis in adolescents remains a major challenge for clinicians due to its diverse clinical picture and ambiguous changes in electrocardiogram (ECG) and transthoracic echocardiography. A mild course of the disease is usually observed in this age group. Often the leading symptom is chest pain preceded by a viral infection. However, the course of the disease can be fulminating, with life-threatening consequences. Acute heart failure can lead to the development of post-inflammatory dilated cardiomyopathy. In predicting prognosis, the most important is to evaluate left ventricular function.

In addition to standard echocardiographic parameters, the left ventricle myocardial performance index (LV MPI, Tei index) can be used to assess left ventricular function. Previous studies using LV MPI indicate that it is a parameter independent of ventricular geometry, heart rate and mitral valve regurgitation.

The purpose of this study was to evaluate LV MPI by echocardiography in children with myocarditis and to investigate the correlations between index values for selected four LV segments and the presence of oedema on T2-weighted cardiac magnetic resonance imaging (CMRI).

MATERIALS AND METHODS

The retrospective study included a group of 32 patients (28 boys and 4 girls) diagnosed with myocarditis who were hospitalized at the University Department of Paediatric Cardiology. The age of the subjects was 16–18 years (mean 16.75 ± 0.44 years).

The control group included 30 adolescents (20 boys and 10 girls) aged 15–18 years (mean 16.37 ± 0.43 years).

In the study group, ultra-troponin I (TnI) concentration was determined, resting 12-lead ECG, two-dimensional echocardiography and CMRI were performed. CMRI was performed in the acute phase of the disease and 9 ± 2 months since its termination.

Serum TnI concentration was tested by microantibody-based chemiluminescence (normal value <19 ng/L). A resting 12-lead ECG assessed the heart rate and repolarisation period.

Echocardiography was performed with the use of Philips EPIQ C7 ultrasound device using an S5-2 transducer with simultaneous ECG recording.

Left ventricle ejection fraction (LVEF) was assessed using the Simpson's method in the apical 4-chamber and 2-chamber views, with planimetric determination of the area in the diastolic and systolic phases and simultaneous ECG recording. LVEF was calculated using the formula: LVEF = (EDV − ESV) / EDV × 100%, where ESV represents left ventricle end systolic volume and EDV represents left ventricle end diastolic volume. The global EF value was automatically averaged using both results from the 2-chamber and 4-chamber views. The lower limit of normal LVEF calculated by Simpson's method was assumed as 55%.

Left ventricular end-diastolic dimension (left ventricular internal diameter in diastole, LVIDd) was assessed by two-dimensional echocardiography in the parasternal long-axis view.

In all adolescents with myocarditis, LV MPI was assessed by echocardiography using the formula LV MPI = (IRT + ICT) / CT, where: CT represents contraction time, ICT represents isovolumic contraction time, IRT represents isovolumic relaxation time. MPI was calculated in four segments: basal anterolateral segment (BALS), basal inferior segment (BIS), IVS (intraventricular septum) basal inferoseptal segment (BISS) and IVS mid inferoseptal segment (MISS).

In all patients with suspected myocarditis, the diagnosis was confirmed by CMRI with gadolinium contrast agent, analysing the same segments where LV MPI was evaluated on echocardiography, noting late gadolinium enhancement (LGE) and features of myocardial oedema.

Results of CMRI performed in the acute phase of myocarditis were compared with follow-up CMRI performed 9 ± 2 months after the disease.

In the control group, history, physical examination, resting 12-lead ECG, two-dimensional echocardiography with evaluation of LVIDd, LVEF and LV MPI in the aforementioned segments were performed.

Statistical analysis was performed using Statistica 13.0 and Microsoft Excel. All variables were compared using *t*-Student test. The distribution of the study groups was assessed as normal. Mean values and standard deviations were calculated for all variables. Correlations were assessed using Pearson's linear correlation coefficient. A p value <0.05 was considered statistically significant.

Using graphs and a four-field table, the sensitivity of all diagnostic tests performed on patients during the diagnostic process was calculated.

Approval from the University Bioethics Committee was obtained for the study.

RESULTS

There were 28 boys (87.5%) in the group of 32 patients with diagnosed myocarditis. The mean age of the boys was

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16.78 ± 0.2 years, and that of the girls was 16.5 ± 0.57 years. The control group included 34 adolescents, including 24 (70.5%) boys; the mean age in this group was 15.8 ± 1.2 years.

Twenty (62.5%) patients with myocarditis were diagnosed with a preceding upper respiratory tract infection on the basis of their history, while 12 (37.5%) had a gastrointestinal infection.

All patients in the study group were admitted to the hospital for chest pain. No patient in the study group showed overt signs of heart failure.

The ECG recordings of all subjects showed sinus rhythm with a heart rate of 58/min to 100/min (mean 76/min). Tachycardia >100/min was observed in 1 patient. No cardiac arrhythmias were registered in any of the patients. Out of the 32 subjects, ECG repolarisation period abnormalities were recorded in 30 (93.75%) patients. In 19 (59.3%) adolescents, the changes involved the left ventricular inferior wall leads (II, III and aVF), while in 11 (34.3%) patients, the changes involved the left ventricular lateral wall leads (I, aVL, V5, V6). The sensitivity of ECG as a diagnostic test in diagnosing myocarditis was 93%. In the control group, all subjects had sinus rhythm; repolarisation abnormalities in leads III and aVF were observed in 10 (29.5%) of 34 children.

The specificity of ECG as a diagnostic test was estimated at 70%. The positive predictive value of ECG as a diagnostic test was 0.75, while the negative predictive value was 0.7 with a prevalence rate was estimated at 0.81.

Out of the 32 patients, serum TnI concentration on the day of admission was above standard in 31 (96.8%) patients and amounted to 1,201–27,148 ng/L (mean 9,120 ± 7,221 ng/L). The sensitivity of TnI concentration as a diagnostic test for diagnosing myocarditis was 96.8%.

On two-dimensional echocardiography, LVEF values in the entire study group of 32 patients ranged from 47% to 65% (mean 56.5 ± 5.2%). In 11 (34.37%) subjects, LVEF was below standard and ranged from 47% to 54% (mean 51.48 ± 2.5%). The sensitivity of LVEF as a test in the diagnostic process of myocarditis was 34%, and the specificity of LVEF was 100%. The mean LVIDd in the study group in M-mode measurements was 49.78 ± 4.6 mm. Only in 2 patients the LVIDd dimension on echocardiography in the group with myocarditis was above the upper limit (Z score >2). In the control group, all subjects had normal LVIDd values (Z score <2) and LVEF in the range of 58–68% (mean 67.63 ± 3.36%). There was no statistically significant difference in LVEF and LVIDd values in the study group, when compared to the control group.

Statistically significant differences were obtained between the mean LV MPI values in the study group and those obtained in the control group – for the basal inferoseptal segment 0.52 ± 0.07 vs. 0.4 ± 0.08 ($p < 0.001$), for the basal anterolateral segment 0.48 ± 0.02 vs. 0.41 ± 0.08 ($p = 0.019$), and for the mid inferoseptal segment: 0.5 ± 0.01 vs. 0.39 ± 0.09 ($p = 0.001$), respectively (Tab. 1, Figs. 1, 2).

	Study group	Control group	*p**
BISS	0.52 ± 0.07	0.4 ± 0.08	0.00035
BASL	0.48 ± 0.02	0.41 ± 0.08	0.019
BIS	0.4 ± 0.02	0.42 ± 0.08	0.048
MISS	0.5 ± 0.01	0.39 ± 0.09	0.001

BISS – basal inferoseptal segment; **BALS** – basal anterolateral segment; **BIS** – basal inferior segment; **MISS** – mid inferoseptal segment.
* At the significance level $p < 0.05$.

Tab. 1. Left ventricular myocardial performance index (LV MPI) values for each segment in the study and control groups

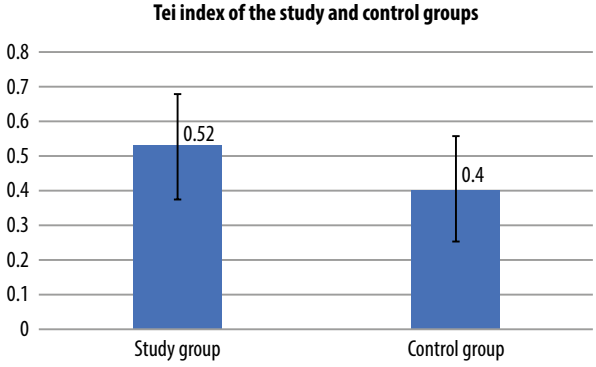

Fig. 1. Comparison of the left ventricle myocardial performance index (LV MPI) values in the basal septal segment in the study and control groups with diagnosed myocarditis

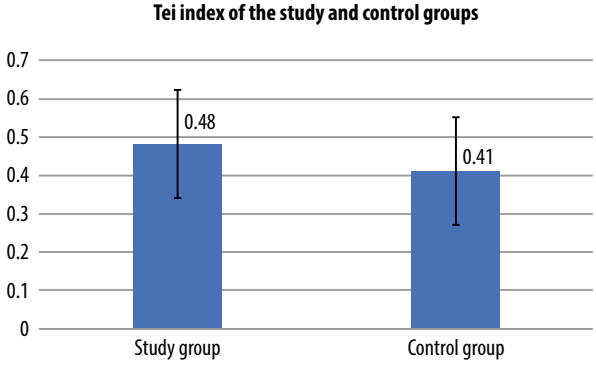

Fig. 2. Comparison of the left ventricle myocardial performance index (LV MPI) values in the basal anterolateral segment in the study and control groups with diagnosed myocarditis

A value of 0.4 ± 0.02 was noted for the basal inferior segment, compared with 0.42 ± 0.08 for the control group ($p = 0.048$). LV MPI values >0.5 were considered significantly elevated. The sensitivity of LV MPI for individual segments on echocardiography as a test in the diagnostic process of myocarditis was 75%.

Correlations between the variables LV MPI, LVEF and LVIDd in the acute phase of the disease were evaluated.

A positive, moderate statistically significant correlation was found between LV MPI and LVIDd (Tab. 2). The correlation coefficient between LV MPI and LVEF was 0.0004, the correlation was not statistically significant.

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	Pearson coefficient (*r*)	
	LV MPI	**LVEF**
LVEF	0.0004	–
LVIDd	0.39	0.08

LV MPI – left ventricle myocardial performance index; **LVEF** – left ventricle ejection fraction; **LVIDd** – left ventricular internal diameter in diastole.
* At the significance level $p < 0.05$.

Tab. 2. Pearson correlation coefficient (r) between the variables LV MPI, LVEF and LVIDd

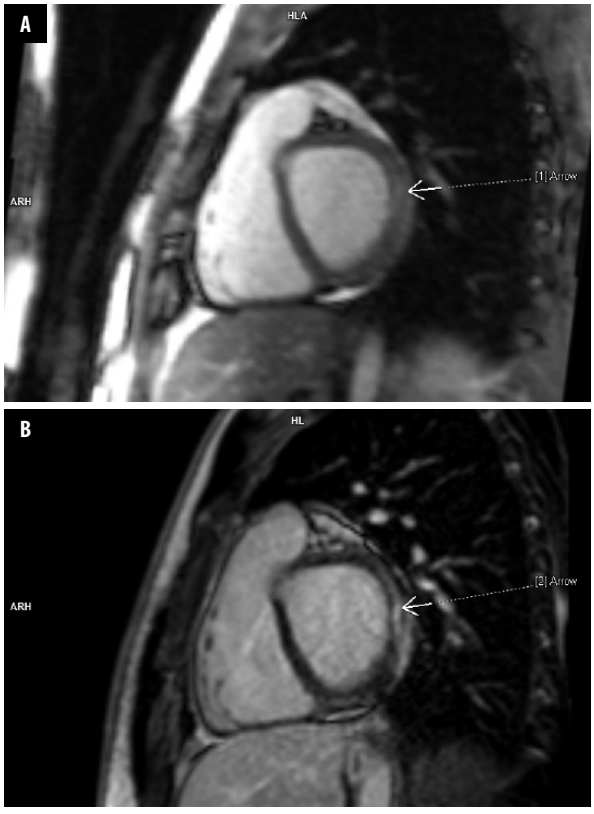

*Fig. 3 A, B. Cardiac magnetic resonance imaging, T2-weighted image (**A**) and late contrast enhancement image (**B**) revealing subepicardial area of oedema (**A**) corresponding to late contrast enhancement (**B**)*

In all subjects with myocarditis, CMRI with gadolinium contrast agent was performed with the indication of segments bearing features of oedema in T2-weighted images and focal late contrast enhancement effect in T1-weighted images, confirming the diagnosis. In all patients from the study group, CMRI showed features of myocardial oedema in T2-weighted images in the basal anterolateral segments (BALS), basal inferior segments (BIS), basal inferoseptal segments (BISS), and mid inferoseptal segments (MISS)) (Fig. 3). In 12 patients in the study group the mean LV MPI value was <0.5, and 8 (66.6%) of them had no residual lesions in the form of endomysial or subepicardial areas of late contrast enhancement on follow-up CMRI after 9 ± 2 months. However, all patients with myocarditis with LV MPI averaging >0.5 had residual lesions on follow-up CMRI performed after 9 ± 2 months.

DISCUSSION

The range of diagnostic tests in young patients reporting with chest pain usually includes ECG, TnI and echocardiography.

Previous retrospective studies indicate low sensitivity of ECG diagnostic tests and low sensitivity, at 30–40%, of basic parameters of two-dimensional echocardiography (LVEF, LVIDd, ratio of mitral inflow velocity and mitral annular velocity in the early diastolic phase)[1,3].

In our study, ECG sensitivity was high at 93%, while LVEF reached only 34%.

The recommended test to confirm the diagnosis of myocarditis is CMRI, and evaluation of myocardial and perivascular space changes is performed according to modified Lake-Louise criteria[2] (myocardial oedema in T2-weighted images and endomysial/subepicardial areas of late contrast enhancement).

In the last 20 years, very few studies analysing the parameter, LV MPI, in the paediatric population have been published.

The results of our own study showed significantly higher sensitivity of LV MPI (75%), when compared to LVEF (34%) calculated by echocardiography in the diagnostic process in patients with myocarditis.

The results are consistent with the study of Yadav et al. who analysed echocardiographic parameters in children with asymptomatic myocarditis in the course of dengue virus infection. The cited authors showed a much lower sensitivity in assessing left ventricular systolic fraction (48%) compared to LV MPI (70%) calculated for basal segments of the left ventricle(1).

In 2022, the results of a more than 10-yearlong study by Mirna et al. including a group of 40 young adults (mean age 35 years) with a confirmed diagnosis of myocarditis, a group of 29 adults with acute coronary syndrome, and a control group of 50 healthy volunteers were published. Parameters of left ventricular systolic and diastolic function in the two study groups were compared with those obtained in the control group. A statistically significant difference was observed in the group of patients with myocarditis, whose left ventricular function index was 0.41, compared with the control group, where the index value was 0.31. In the group of patients with myocardial damage of ischemic origin, the mean value of left ventricular function index was 0.35, and it was not statistically significantly different from the control group[3].

No publication evaluating LV MPI in paediatric population with myocarditis was found in the available literature. Individual reports have indicated the usefulness of LV MPI for assessing left ventricular function in inflammatory diseases.

Ajami et al. observed elevated LV MPI in children with acute Kawasaki disease, which normalized after several weeks of observation[4].

In contrast, Thorburn et al. demonstrated abnormally high LV MPI values of right ventricular segments in children

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with severe respiratory syncytial virus infection. In the cited study, no cardiac MRI was performed to confirm myocardial oedema[5].

The myocardial performance index is also used in foetal cardiology. Tsutsumi et al. were the first to describe the Tei index in foetuses. They showed a gradual decrease in the value of the index with the duration of pregnancy, which they explained by the improvement of myocardial performance with foetal growth[6]. Currently, LV MPI is used in prenatal cardiology centres in clinical practice to assess foetal well-being.

Based on our own study, it should be emphasized that LV MPI is a simple and accessible parameter to assess left ventricular myocardial performance, which can be a complementary method in the diagnosis of myocarditis.

LIMITATIONS OF THE STUDY

The limitations of the study involved its retrospective nature and the small size of the study and control groups.

CONCLUSIONS

1. LV MPI values on echocardiography are elevated in children with myocarditis.
2. LV MPI has proven to be a valuable parameter in the diagnosis of myocarditis in children.
3. Higher LV MPI values indicate a longer inflammatory process, as reflected by cardiac magnetic resonance imaging (CMRI).
4. Continued prospective studies will allow to determine whether LV MPI is useful to evaluate prognosis in children with myocarditis.

Conflict of interests

The authors report no financial or personal relationships with other individuals or organisations that could adversely affect the content of the publication and claim rights to this publication.

Author contribution

Original concept of study; final approval of manuscript: MJ, BW. Collection, recording and/or compilation of data; writing of manuscript: MJ. Analysis and interpretation of data; critical review of manuscript: MJ, MF, BW.

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