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REVIEW ARTICLE
ОБЗОРНАЯ СТАТЬЯ

Speckle tracking echocardiography in patients with diabetes mellitus: a systematic review

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Abstract. *Relevance* Speckle tracking echocardiography (STE) constitutes a notable progression in the realm of non-invasive cardiac imaging, facilitating accurate quantification of myocardial deformation across various planes. This modality surpasses traditional echocardiographic metrics, such as left ventricular ejection fraction (LVEF), by allowing for the early identification of subclinical myocardial dysfunction. This review delineates the foundational principles and technological advancements associated with STE, encompassing the incorporation of deep learning algorithms, high-frame-rate imaging, and three-dimensional applications that enhance tracking precision and clinical applicability. Particular attention is directed toward the significance of global longitudinal strain (GLS) as a sensitive biomarker indicative of early systolic impairment. The clinical significance of STE is particularly pronounced in individuals with type 1 diabetes mellitus (T1DM), a cohort that is at an increased risk for the onset of cardiovascular complications. Numerous studies illustrate that STE can detect myocardial strain abnormalities in diabetic patients well in advance of the appearance of overt cardiac symptoms or declines in LVEF. This capability facilitates the earlier recognition of diabetic cardiomyopathy, enhances the monitoring of therapeutic responses, and permits risk stratification based on parameters such as GLS and atrial strain. *Conclusion*: STE has emerged as an invaluable instrument in contemporary cardiology, particularly for the diabetic demographic, where it unveils subtle myocardial dysfunction frequently overlooked by conventional methods. Its expanding role in cardio-oncology, heart failure management, and diabetes care underscores the necessity for broader clinical integration. Nevertheless, additional prospective, outcome-based studies are imperative to validate its prognostic significance and to effectively incorporate it into standard clinical practice. By bridging the divide between imaging and early intervention, STE presents promising trajectories for the enhancement of long-term cardiovascular outcomes.

Keywords: speckle tracking echocardiography (STE), global longitudinal strain (GLS), myocardial deformation, diabetes mellitus, subclinical cardiac dysfunction, diabetic cardiomyopathy

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Introduction

Speckle tracking echocardiography (STE) is a method of examining the heart using ultrasound, which allows you to assess the work of the heart muscle at each point over several heart cycles. This method allows you to accurately measure both total and regional myocardial deformity, which gives a detailed picture of the systolic function of the myocardium. Such as ejection fraction, are normal. STE allows you to assess the performance of both the left and right ventricles, as well as the atria, using parameters such as global longitudinal deformity (GLS), which is a more sensitive indicator of early systolic dysfunction, torsional deformity, and circular deformity [1].

Speckle-tracking echocardiography was developed as a method that provides a reliable assessment of the movement of tissue displacements using unique speckle templates generated by ultrasound imaging. Speckle tracking algorithms were originally based on the use of optical flow and block-matching techniques. These methods made it possible to accurately assess the movement of specific tissue areas by tracking speckle patterns on ultrasound images over several cardiac cycles. To improve lateral resolution, the method was developed by applying advanced techniques such as the Riess transform, which extends the Hilbert transform into a multidimensional space, increasing the lateral resolution accuracy [1, 2]. The evolution of speckle-tracked echocardiography (STE) has further refined the method, allowing the quantification of regional myocardial function and providing a more sensitive assessment of left ventricular dysfunction compared to traditional approaches such as ejection fraction [3]. Innovation continued with the introduction of convolutional neural networks (CNNs) to detect tracked speckle patches, which significantly reduced tracking errors and improved accuracy [4]. The emergence of deep learning models such as the Neural Network for Unsupervised Motion Estimation (UMEN-Net) allowed for the refinement of the method by using RF echoes before and after deformation to infer displacement fields, which improved the assessment of axial and lateral deformation [4]. In addition, methods such as two-dimensional iterative projection (TDIP) and the use of dynamic nuclei in speckle tracking have been proposed to improve the accuracy and efficiency of estimating the blood flow velocity profile. These methods have proven to be applicable in various clinical situations [5]. The combined implementation of these advances has contributed to improved reliability and accuracy of motion assessment in ultrasonic speckle tracking, making it a valuable tool for medical diagnosis and treatment monitoring.

The basic idea is to track the movement of granular patterns, known as speckles, which are formed by the scattering of ultrasound waves in tissues, on successive ultrasound frames. This assessment can be carried out in a variety of directions — longitudinal, radial, and circular — to provide a comprehensive assessment of tissue mechanics [6]. The process begins with tissue segmentation, after which traceable speckles are extracted, which can be improved using ultra-precise neural networks (CNNs) to improve the accuracy of the result [7, 8, 9]. Another significant advancement is the use of high-frequency frame echocardiography, which contributes to more detailed and faster imaging of speckles, which is critical for accurate motion tracking in three-dimensional (3-D) echocardiography[10]. Interpretation of image analysis utilizing the American Heart Association (AHA) framework delineates the regional wall segments of the left ventricle (LV) across various echocardiographic and tomographic perspectives. This approach facilitates the integration of conventional two-dimensional views with the 17-segment model employed for the analysis of strain and perfusion. (Fig. 1) [11].

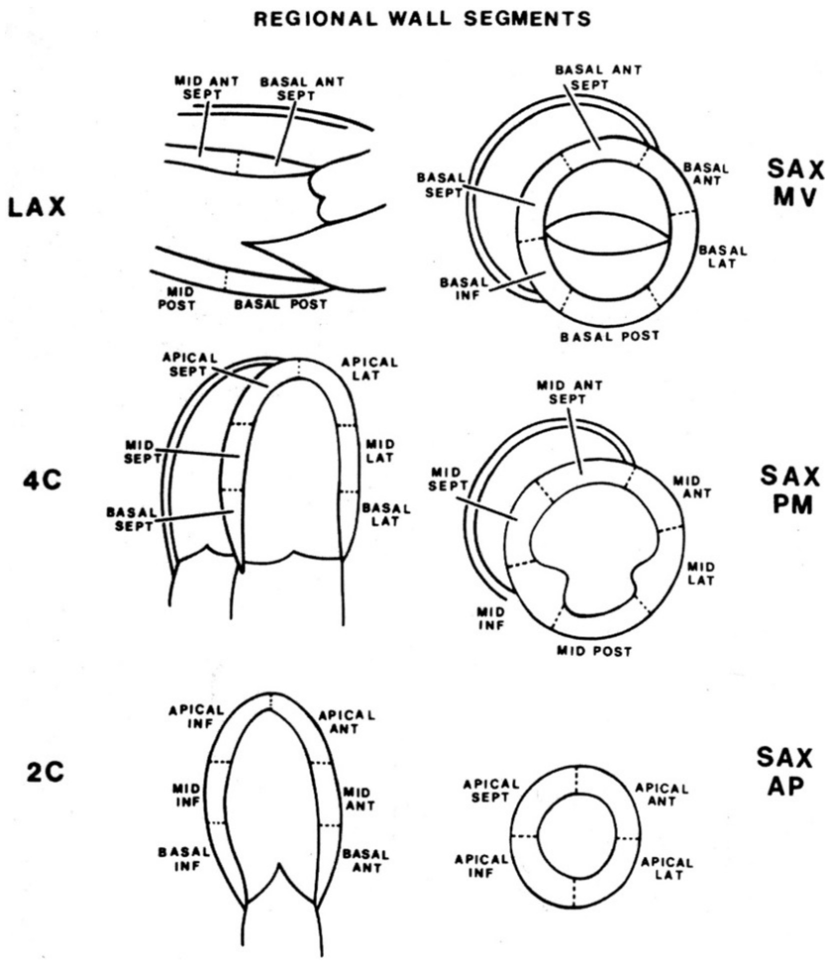

Fig.1. Diagram of the left ventricle segments for 2D echocardiography [11, modified]

Note: LAX—Long Axis View — shows vertical long-axis of left ventricle; 4C -(four-chamber view) cuts through both left and right ventricle chambers; 2C (two-chamber view) excludes right ventricle; focused on anterior and inferior left ventricular walls; SAX (short axis views — viewed at levels of MV (short axis view at mitral valve); SAX PM (short axis view at papillary muscle level); SAX AP (short axis view at apex level).

Global longitudinal deformity (GPD) is an important echocardiographic indicator that evaluates myocardial deformity, especially longitudinal shortening of the left ventricle, and is considered a reliable indicator for assessing left ventricular systolic function. The main elements of GPD include accurate acquisition of high-quality images, often by speckle-tracking echocardiography or magnetic resonance imaging (MRI), and subsequent analysis of myocardial deformity in various segments of the left ventricle [12].

GPD is calculated by averaging the strain values across these segments, which reduces the influence of noise and observer variability, making this indicator more reliable compared to the left ventricular ejection fraction (LVEF) [13].

The clinical value of the use of GPD applies to a variety of cardiovascular diseases, including heart failure, myocardial infarction, and chemotherapy-induced cardiotoxicity, where it demonstrates a higher predictive value compared to conventional measures such as LVEF [14]. The use of GPD is significant for the detection of subclinical myocardial dysfunction, even with preserved LV EF, and is a marker of adverse cardiovascular events and mortality in both symptomatic and asymptomatic patients with heart failure [15]. The GPD method is included in the guidelines of cardio-oncology [16] for the early detection of chemotherapy cardiotoxicity, allowing for timely adjustment of the dose of anticancer therapy. Despite its advantages, the assessment of the prognostic value of GPD in some conditions, such as ejection fraction preserved heart failure (HFpEF), remains a matter of debate, highlighting the importance of further research to confirm its clinical relevance in different patient populations. Given the above, GPD is a sensitive tool for assessing myocardial function, which should be used to monitor patients in dynamics and assess the prognosis of patients with various cardiovascular pathologies. Global longitudinal strain (GPD) values: The normal range for GPD, which measures how much the heart muscle shortens during heart contraction, has been shown to range from –15.9 to –22.1%, with a mean of –19.7% (95% confidence interval: –20.4 to –18.9%). Global Circular Deformation (GCD) values: For the GCD indicator, which measures the force of circular torsion of the myocardium, the normal range is –20.9 to –27.8%, with a mean of –23.3% (95% confidence interval: –24.6 to –22.1%). Global radial deformity (GRD) values: The normal range for GRD assessing heart muscle thickening during ventricular systole is 35.1 to 59.0%, with a mean of 47.3% (95% confidence interval: 43.6 to 51.0%) [17]. GLS has been employed as a predictive measure for unfavorable left ventricular remodeling in individuals who have undergone a myocardial infarction (MI). It delineates elevated pulse wave velocity (PWV) and diminished global longitudinal strain (GLS) as autonomous predictors of adverse remodeling outcomes. The investigation encompassed a cohort of 112 patients, stratified into two groups predicated upon the presence of ST-segment elevation. The findings elucidate that an increased initial PWV is associated with a diminished efficacy in the recovery of left ventricular systolic function. The outcomes underscore the significance of monitoring PWV and GLS to enhance therapeutic strategies following MI [18].

Interpretation of image analysis utilizing the framework established by the American Heart Association (AHA) delineates the regional wall segments of the left ventricle (LV) as observed through various echocardiographic and tomographic perspectives. This framework facilitates the integration of conventional two-dimensional views with the 17-segment model employed for the assessment of strain and perfusion dynamics (Fig. 2) [19, modified].

Possibilities of using the technique of speckle tracking-echocardiography in patients with diabetes mellitus

Studies show that inadequate glycemic control in patients with diabetes mellitus negatively affects left ventricular (LV) function, which can lead to a decrease in LV EF and an increase in the incidence of heart failure (HF) [20, 21]. Patients with diabetes mellitus often develop heart failure with preserved ejection fraction, in which there is a deterioration in ventriculo-arterial interaction and an increase in arterial stiffness, which exacerbates the course of HF, so early detection of myocardial dysfunction plays an important role.

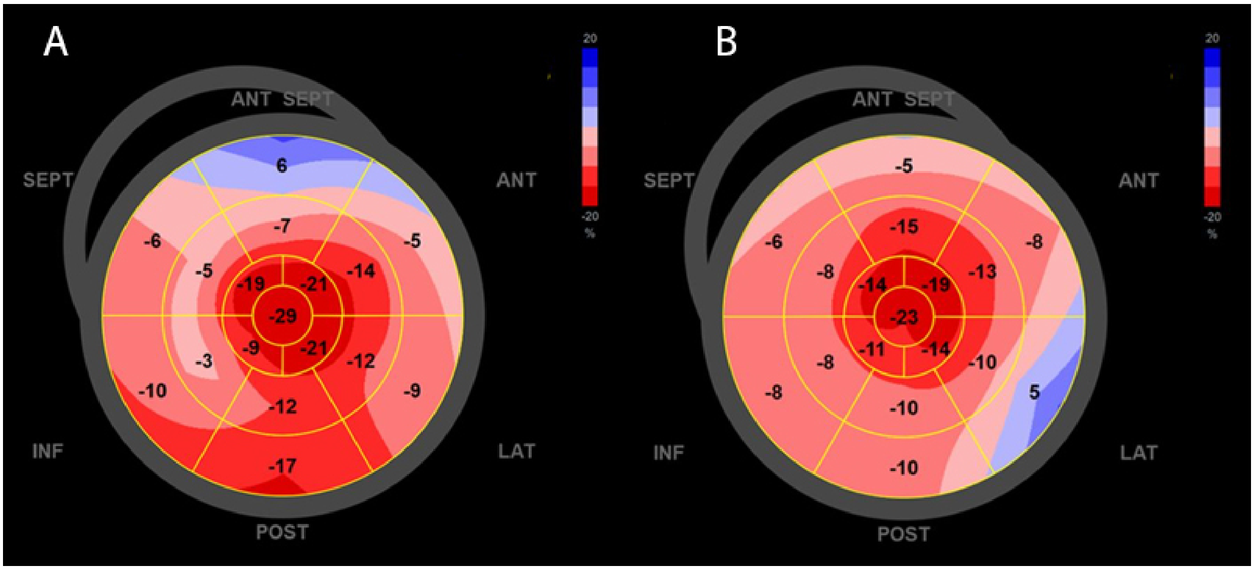

Fig. 2. Plots of the left ventricle 17-segments model [19, modified].

Note: Plot A: most values are highly negative (e. g., −29%, −21%, −19%), indicating strong contraction. One segment shows a positive value (6%) in the anterior septal area, indicating reduced or paradoxical motion. Likely suggests localized dysfunction in that anterior region. Plot B: overall slightly less negative strain values compared to B (e. g., −23%, −15%, −14%). A positive strain value (5%) appears in the lateral region, possibly suggesting abnormal movement in that area.

Studies show that GPD is a more sensitive indicator for detecting subclinical cardiac dysfunction in patients with diabetes mellitus compared to traditional echocardiographic indicators. GPD is a more sensitive method in detecting early myocardial damage, even if LV EF is intact [22, 23].

Various methods of speckle-tracking echocardiography have been studied to assess the deformation properties of the myocardium in patients with diabetes mellitus.

Lehner LJ study (follow-up period of 3 years from 2013 to 2016), where a retrospective analysis was performed to assess GPD in three groups [24]. The first group consisted of patients with type 1 diabetes mellitus and renal insufficiency (PI) (type 1 DM + PI) (n=16). The second group consisted of patients with PI without type 1 DM (n=20). The third group consisted of a control group with healthy volunteers (n=48). Echocardiography with GPD assessment in patients with type 1 diabetes mellitus + PN and in the renal insufficiency group showed that GPD was significantly lower in both groups compared to healthy volunteers. Global longitudinal deformity in the group of patients with type 1 diabetes + PN: -13.07 ± 2.67%, GPD was slightly better in the group of patients with PN without DM: -14.68 ± 4.87%. The GPA in the healthy volunteer group was significantly higher compared to patients in the other groups: -19.78 ± 1.89%, indicating that LV function was better among healthy volunteers. Global radial and circular deformity in patients with type 1 diabetes + PN is worse, which confirms the effect of diabetic microvasculopathy on the myocardium.

A study by Mayumi Ifuku studied left atrial dysfunction using echocardiography in children and adults with type 1 diabetes mellitus (type 1 diabetes) [25]. A total of 53 patients with type 1 diabetes mellitus aged 5 to 41 years (mean age 23 years) were included, the patients were divided into three age groups: D1 (5–14 years), D2 (15–24 years), and D3 (25–41 years). Control groups comparable in age and sex were also divided into corresponding groups (C1, C2, and C3) for comparison. All underwent echocardiography to assess left atrium (LP) function with deformity analysis. LP stiffness was significantly higher in patients with type 1 diabetes aged 25–41 years compared to the control group, which indicates an increase in LP stiffness with age in patients with type 1 diabetes. The data obtained indicate that LP function decreases in adolescents and young people with type 1 diabetes, while LP stiffness increases in patients over 30 years of age. Which indicates potential early markers of diastolic dysfunction. The age range of participants was wide (5–41 years), which could introduce variability in the results due to different life stages and disease progression. The study did not examine the effect of glycemic control or the duration of diabetes on LV function, which may provide additional clues about the relationship between type 1 diabetes and LV dysfunction. The Thousand & 1 study is one of the largest in Denmark, initiated by Magnus Jensen and Peter Sogaard [26]. A total of 1065 patients with type 1 diabetes mellitus without heart disease, the control group (n=198) were included. All underwent standard and 2D speckle-tracking echocardiography to measure global longitudinal deformity and assess systolic function. Patients were divided into groups based on albuminuria status: normoalbuminuria (n=739), microalbuminuria (n=223), and macroalbuminuria (n=103). The study aimed to determine whether myocardial systolic function was impaired in all patients with type 1 diabetes or only in patients with albuminuria with healthy people, which indicates the absence of specific diabetic cardiomyopathy in this subgroup. With stratification by albuminuria status, the difference in GPD compared to controls was –18.8 ± 2.5% in normoalbuminuria ($p = 0.28$), and –17.9 ± 2.7% in microalbuminuria ($p = 0.001$). Notably, patients with type 1 diabetes without albuminuria exhibited myocardial systolic function similar to healthy individuals. However, the authors emphasized that the presence of subclinical coronary artery involvement was not known. The study did not examine long-term LV systolic function in different patient groups.

In the study of Mihaela Berceanu, the main objective was to study the right ventricle using conventional echocardiography and speckle-tracking echocardiography [27]. The study included 60 young people diagnosed with type 1 diabetes mellitus at an average of 9.7 ± 6.3 (2–27) years old, and a control group (n=90). The images and measurements obtained from echocardiography were analyzed using the special EchoPAC BT13 software. The study used STEs to measure deformities in different segments of the right ventricle (basal, middle, and apical), but no significant differences were found in these deformity measurements between the diabetic group and the healthy group of individuals, indicating that the ability of the heart muscle to contract was similar in both GLS RV groups globally (%) –22.4 ± 0.5, GLS RV free wall (%) –26.4 ± 4.3, GLS RV basal (%) –25.5 ± 4.9, GLS RV mean (%) –28.7 ± 4.6, GLS RV apical (%) — 25.3 ± 6.03 segments. Conventional echocardiographic parameters showed that in the group of diabetics, the rates on the tricuspid ring (Et and At) and the Et/At ratio of 0.9 ± 1 were reduced compared to the control group, which indicates an impaired ability of the right ventricle to fill with blood (decreased diastolic function) in young people with type 1 diabetes.

MAGYAR-Path study (analysis of the movement of the heart and great vessels using 3D speckle tracking echocardiography in various patients) [28]. Prospective analysis of 17 patients with type 1 diabetes mellitus who received insulin through a pump and were not obese, mean age of 33.5 years, of which 8 were men. 20 healthy participants, were comparable in age and sex, mean age — 36.9 years. In the course of the study, various volumetric parameters of the LP were measured, including maximum and minimum volumes, as well as volume before atrial contraction. In addition, to assess functional changes in the LP, such deformity parameters as segmental circular deformity, basal longitudinal deformity, and 3-D echocardiography of the atria were analyzed, and healthy volunteers. Total atrial stroke volume increased (23.6 ± 6.9 mL vs. 19.6 ± 4.6 mL, $p = 0.04$), while segmental circular deformity was reduced (28.9% ± 11.4% vs. 37.3% ± 12.5%, $p = 0.04$). In particular, patients with type 1 diabetes had increased LP volumes and altered deformity parameters, indicating early LP remodeling in these patients. The study did not include the assessment of clinical outcomes and focused on echocardiographic parameters and did not assess clinical outcomes such as the incidence of atrial fibrillation or heart failure, which are important for understanding the clinical significance of LP dysfunction in patients with type 1 diabetes.

Fridolfsson from the Department of Clinical Physiology in Kalmar (Sweden) conducted a study that included 43 people with type 1 diabetes recruited from diabetes clinics and schools in Sweden, which ensured that the control group was matched by age and sex and 43 healthy people aged 10—30 years [29]. A significant negative correlation was found between the average level of HbA1c and PALS (peak atrial longitudinal strain), left atrial conduit strain, which indicates that better metabolic control is associated with better left atrial function (r = — 0.3, $p < 0.05$) and conduit deformity (r = — 0.4, $p < 0.05$). However, the higher left atrial stiffness found in young participants with type 1 diabetes, may be associated with earlier onset of disease in this group, and the results should be interpreted with caution in the younger adult population.

Taghreed A. Ahmed and researchers found that young adults with type 1 diabetes have early signs of heart dysfunction even if they did not have any symptoms, highlighting the importance of early detection of symptoms of myocardial dysfunction for timely correction [30]. The study involved 30 young patients with type 1 diabetes and 15 healthy controls for a total of 45 participants. The diabetic group consisted of 10 men and 20 women, with an average age of 20.9 years, while the control group consisted of 5 men and 10 women, with an average age of 23.8 years. 2D speckle tracking echocardiography (2D-STE) was used as the main diagnostic tool, which revealed a significant decrease in the mean peak global longitudinal deformity of the LV and the peak global longitudinal deformity of the LP in diabetic patients compared to non-diabetics, indicating early cardiac dysfunction in the group of diabetics (15.8 ± 6.8 and 23.9 ± 2.7, respectively; P < 0.001) and LV strain rates using the Strain-Raine technique (19.7 ± 5.4 and 23 ± 2.7, respectively P < 0.05). Although the study assessed functional capacity using the treadmill test, no significant differences were found between the diabetic and control groups, which may indicate that the test is not sufficiently sensitive to detect early myocardial functional impairment.

The study by Berceanu M. included 50 adults with type 1 diabetes and 80 healthy volunteers [31]. The study showed that although the total pumping capacity of the heart (ejection fraction) was similar in the two groups, in the type 1 diabetes group, the myocardial deformation properties in different layers were reduced, indicating early cardiac dysfunction of the GPD in the endocardium and myocardial GPD (–20. ± 2.7 vs. –22. ± 2.3 and –18.0 ± 2.4 vs. –19.1 ± 1.9, respectively, $p < 0.05$) compared to the control group. Measurements of pancreatic deformity did not reveal significant differences between the groups. Only those who had been diagnosed with type 1 diabetes for at least one year were included in the study, which means that the findings may not apply to those who were diagnosed with the disease within a shorter period or recently. In this work, the researchers did not have data on the presence and extent of albuminuria, a condition that in previous studies was strongly correlated with global longitudinal deformity, which did not allow an assessment of the effect of albuminuria on myocardial deformation properties.

Jędrzejewska Ip study included 50 young adults with type 1 diabetes and 50 healthy adults of the same age as a control group to compare heart function between the two groups [32]. They specifically measured left ventricular global longitudinal deformity (LV GPD), left ventricular global circular deformity (LV GCD), basal left ventricular radial deformity (LV-basal GRD), and right ventricular free wall global longitudinal deformity (RV GPD) to assess the heart's pumping capacity. On the day of the echocardiography, blood samples were taken to measure NT-proBNP, glycated hemoglobin (HbA1c), and microalbuminuria, which are indicators of cardiac workload, blood sugar control, and kidney function, respectively. Multivariate logistic regression analysis showed that the only dependent predictor of LV GPD reduction was low-density lipoprotein [odds ratio 3.65 (95% confidence interval: 1.27–10.5), P 1/4 0.014] LV GPD (220.3 + 2.0% vs. 222.2 + 1.8%, P, 0.001), LV HCD (221.1 + 2.5% vs. 222.2 + 2.4%, P, 0.05), LV-basal GD (50.5% + 11.5 vs. 57.1% +17.0, P, 0.05), and RV GPD (230.1% + 3.5 vs. 232.7% + 3.9, P, 0,01).

A study by Bogdanović J. included asymptomatic patients with diabetes mellitus without cardiovascular disease, divided into three groups: acute hyperglycemia (group A), optimal metabolic control (group B), and healthy control (group C) [33]. The study included three groups: Group A — 67 patients with acute hyperglycemia, Group B — 20 patients with optimal metabolic control, and Group C — 20 healthy individuals as controls. Group A had significantly higher blood glucose levels (22.5 ± 1.1 mmol/L) compared to Group B (5.8 ± 0.2 mmol/L) and Group C (5.1 ± 0.1 mmol/L). The 2D-STE was used to assess global and regional left ventricular (LV) function by multilayer strain analysis, including global longitudinal deformity (GPD) and peak systolic longitudinal and circular deformity in different myocardial layers (endocardial, myocardial medial, and epicardial) The study showed that the global longitudinal deformity in patients with acute hyperglycemia (group A) (–19. 6 ± 0.4%) was significantly lower compared to patients with optimal metabolic control (group B (–21.3 ± 0.4%; $p < 0.05$)) and healthy subjects (group C (–21.9 ± 0.4%; $p < 0.01$)) at baseline, suggesting impaired cardiac function in group A. Peak systolic longitudinal deformity in the endocardial (Endo), myocardial (Myo), and epicardial (Epi) layers was significantly lower in group A compared to group B and group C at baseline, This indicates the effect of acute hyperglycemia on all layers of the heart muscle. Group A had lower peak systolic longitudinal deformity in the endocardial (–22.8 ± 0.4%), myocardial (–19.7 ± 0.3%), and epicardial (–17.4 ± 0.3%) layers compared to groups B and C. A marked worsening of peak systolic circular deformity in the basal level of the left ventricle in all three layers (Endo, Myo, and Epi) and at the mean level in the cavity in the Epi layer in group A compared to group C indicates that acute hyperglycemia also affects the circular contraction of the heart muscle. Despite achieving normal blood glucose levels (euglycemia) after 72 hours of continuous insulin treatment and maintaining good glycemic control for three months, global longitudinal strain and peak systolic longitudinal and circular torsion did not improve in group A, suggesting that the negative impact of acute hyperglycemia on cardiac function is not reversible within three months.

The investigation conducted by Hajdu et al in the Heart Institute at the University of Pécs encompassed a cohort of 70 asymptomatic individuals diagnosed with type 1 diabetes mellitus (T1DM), with a mean age of 38.2 years and a demographic composition comprising 46 females [34]. Furthermore, the study incorporated 30 healthy volunteers to facilitate comparative analysis. The methodology employed for participant selection in this study is not explicitly articulated in the available documentation; nonetheless, it may be deduced that the patients were chosen based on their T1DM diagnosis and their asymptomatic condition, while the healthy volunteers functioned as a control cohort. The primary aim of the study was to elucidate the effect of current HbA1c levels on left ventricular global longitudinal strain (GLS), circumferential strain (GCS), and atrial strain parameters, in addition to evaluating the impact of age and hypertension on these associations. The findings of the study indicated that the quality of glycemic control, as evidenced by HbA1c levels, exerts a significant influence on myocardial mechanics in asymptomatic patients with type 1 diabetes mellitus (T1DM). In particular, a current HbA1c level emerged as an independent predictor of left ventricular global longitudinal strain (GLS), circumferential strain (GCS), and atrial strain parameters. Patients exhibiting HbA1c levels exceeding 7.4% demonstrated compromised myocardial mechanics, whereas those with HbA1c levels at or below 7.4% and without hypertension presented echocardiographic results akin to those of healthy volunteers.

The investigation conducted by Abdel-Salam et al. sought to examine the preliminary alterations in regional left ventricular systolic and diastolic performance in young asymptomatic individuals diagnosed with type 1 diabetes mellitus, utilizing speckle-tracking echocardiography (STE) as the evaluative tool [35]. The study incorporated a cohort of 60 subjects, comprising 30 normotensive asymptomatic individuals with type 1 diabetes mellitus (DM) aged 40 years or below, alongside 30 age-matched healthy controls. The participant selection process was predicated on specific inclusion criteria: individuals needed to have a diabetes duration exceeding 5 years and a left ventricular ejection fraction of 50% or more, thereby ensuring a comparably homogenous cohort for analysis relative to the control group. The research aimed to compare the myocardial deformation metrics of the diabetic population against those of the healthy controls to discern any statistically significant variances in cardiac functionality, with particular emphasis on global longitudinal systolic strain and strain rates. The investigation evaluated early alterations in regional left ventricular functionality in young asymptomatic patients with type 1 diabetes mellitus employing speckle-tracking echocardiography. The findings elucidated that global longitudinal systolic strain and strain rate were markedly diminished in the diabetic cohort in comparison to their healthy counterparts (–17.7 ± 2.5% vs. –21.2 ± 1.7%, $P < 0.001$; –1.1 ± 0.2 vs. –1.3 ± 0.2 s-1, $P = 0.003$). Furthermore, diastolic function exhibited impairment as evidenced by conventional echocardiography and tissue Doppler imaging, underscoring the presence of early cardiac dysfunction within this demographic.

The investigation conducted by Ringle et al evaluated the long-term progression of left ventricular performance in asymptomatic individuals diagnosed with type 1 diabetes mellitus, employing both 2D and 3D speckle tracking echocardiography across a duration of six years [36]. At the initial assessment, the diabetic cohort demonstrated compromised longitudinal function, evidenced by a statistically significant reduction in both 2D-global longitudinal strain (GLS) and 3D-GLS relative to the control group. Subsequent evaluations indicated a slight deterioration in longitudinal function over time; however, no clinical indications of heart disease were detected, as there were no registered fatalities or instances of heart failure. The research encompassed a total of 66 asymptomatic individuals with type 1 diabetes lacking any cardiovascular risk factors, juxtaposed with 26 appropriately matched healthy controls, thereby constituting a comprehensive sample size of 92 participants. The sampling methodology entailed a comparative analysis between the diabetic individuals and healthy controls, with a subset of 14 diabetic patients undergoing a longitudinal follow-up evaluation spanning six years to investigate the long-term changes in left ventricular function. The investigation established that asymptomatic type 1 diabetic patients demonstrated diminished longitudinal function as assessed by both 2D and 3D speckle tracking echocardiography at the baseline, revealing significant disparities in global longitudinal strain (GLS) when contrasted with the matched healthy controls. Over the six-year follow-up period, a modest decline in longitudinal function was observed among the diabetic patients, suggesting a progression towards subclinical myocardial dysfunction. Notably, despite the documented reduction in longitudinal function, the study found that global circumferential strain (GCS) and radial strain (GRS) exhibited stability throughout the study duration. Furthermore, the metabolic status displayed no correlation with GLS; however, GCS and GRS exhibited a compensatory enhancement in function among patients with prolonged diabetes and microvascular complications, indicating potential adaptive mechanisms in response to the pathophysiological condition.

The principal aim of the investigation conducted by Zheng Li is to examine the utilization of the three-dimensional speckle tracking imaging technique (3D-STI) for the assessment of left ventricular systolic function (LVSF) in individuals diagnosed with diabetes mellitus (DM) [37]. The research endeavors to perform a meta-analysis to quantify myocardial function in patients with DM by juxtaposing myocardial strain measurements acquired via 3D-STI against those of a control cohort. The demographic sample encompassed 970 participants sourced from 9 distinct studies that were subjected to analysis in the meta-analysis. The sampling methodology entailed the extraction of electronic databases from the earliest available date up to 29 April 2023, albeit specific information regarding the sampling techniques employed in the individual studies remains unspecified. The findings of the study indicated that, although there was no statistically significant difference in left ventricular ejection fraction between diabetic individuals and control subjects ($P > 0.05$), notable disparities were observed in myocardial strain metrics, encompassing global longitudinal strain, global circumferential strain, global radial strain, and global area strain, all exhibiting significant variations (all $P < 0.05$) between the two groups. The investigation concluded that the three-dimensional speckle tracking imaging technique (3D-STI) demonstrates efficacy in precisely quantifying early left ventricular systolic function impairment in patients with diabetes mellitus, underscoring its potential utility for the early identification of diabetic cardiomyopathy.

Conclusion

Speckle tracking echocardiography (STE) has become a valuable imaging tool for assessing myocardial function in cardiology, especially in patients with diabetes mellitus. By providing an accurate assessment of myocardial deformity using the STE technique, this study allows for an objective assessment of the deformity properties of the various layers of the heart, which makes it possible to detect subclinical myocardial dysfunction early and monitor the progression of this dysfunction over time. However, the significance of subclinical lesions detected by STE in patients with diabetes mellitus is not completely clear in practical terms for doctors, which suggests the need to obtain more convincing evidence for the early detection of subclinical myocardial dysfunction and its further impact on the strategy and results of treatment of patients with type 1 diabetes mellitus. Further research focusing on long-term outcomes and identifying the potential benefits for patients from using the STE technique will help find common ground between researchers and clinicians.

References / Список литературы

1. Garcia D, Lantelme P, Saloux E. Introduction to speckle tracking in cardiac ultrasound imaging. *Handbook of Speckle Filtering and Tracking in Cardiovascular Ultrasound Imaging and Video.* 2018;26:571—598. doi: 10.1049/PBHE013E_CH26
2. Azarmehr N, Ye X, Howes JD, Docking B, Howard JP, Francis DP, Zolgharni M. An optimisation-based iterative approach for speckle tracking echocardiography. *Med. Biol. Eng. Comput*. 2020;58(6):1309—1323. doi:10.1007/s11517-020-02142-8
3. Kusunose K. Is global longitudinal strain a gold standard parameter in all cardiovascular diseases. *Heart.* 2021;107:776—777. doi: 10.1136/HEARTJNL-2020-318876
4. Karageorgos GM, Liang P, Mobadersany N, Gami P, Konofagou EE. Unsupervised deep learning-based displacement estimation for vascular elasticity imaging applications. *Phys. Med. Biol*. 2023;68(15):10.1088/1361—6560/ace0f0. doi:10.1088/1361-6560/ace0f0
5. Rebholz B, Zheng F, Almekkawy M. Two-dimensional iterative projection method for subsample speckle tracking of ultrasound images. *Med. Biol. Eng. Comput*. 2020;58(12):2937—2951. doi:10.1007/s11517-020-02264-z
6. Yingchoncharoen T, Agarwal S, Popović ZB, Marwick TH. Normal ranges of left ventricular strain: a meta-analysis. *J. Am. Soc. Echocardiogr*. 2013;26(2):185—191. doi:10.1016/j.echo.2012.10.008
7. Zhou SK, Greenspan H, Davatzikos C, Duncan JS, van Ginneken B, Madabhushi A, Prince JL, Rueckert D. A review of deep learning in medical imaging: Imaging traits, technology trends, case studies with progress highlights, and future promises. *Proc. IEEE Inst. Elect.r Electron Eng*. 2021;109(5):820—838. doi:10.1109/JPROC.2021.3054390
8. Chen C, Qin C, Qiu H, Tarroni G, Duan J, Bai W, Rueckert, D. Deep Learning for Cardiac Image Segmentation: A Review. *Front. Cardiovasc. Med*. 2020;7:25. doi:10.3389/fcvm.2020.00025
9. Painchaud N, Duchateau N, Bernard O, Jodoin PM. Echocardiography Segmentation with Enforced Temporal Consistency. *IEEE transactions on medical imaging*. 2022;41(10):2867—2878. doi.org/10.1109/TMI.2022.3173669
10. Gao L, Lin Y, Ji M. Clinical Utility of Three-Dimensional Speckle-Tracking Echocardiography in Heart Failure. *J. Clin. Med*. 2022;11(21):6307. doi:10.3390/jcm11216307
11. Cerqueira MD, Weissman NJ, Dilsizian V, Jacobs AK, Kaul S, Laskey WK, Pennell DJ, Rumberger JA, Ryan T, Verani MS, American Heart Association Writing Group on Myocardial Segmentation and Registration for Cardiac Imaging. Standardized myocardial segmentation and nomenclature for tomographic imaging of the heart. A statement for healthcare professionals from the Cardiac Imaging Committee of the Council on Clinical Cardiology of the American Heart Association. *Circulation*. 2002;105(4):539—542. doi.org/10.1161/hc0402.102975
12. Gherbesi E, Gianstefani S, Angeli F. Myocardial strain of the left ventricle by speckle tracking echocardiography: From physics to clinical practice. *Echocardiography*. 2024;41(1): e15753. doi:10.1111/echo.15753
13. Kouris NT, Kostopoulos VS, Psarrou GA, Kostakou PM, Tzavara C, Olympios CD. Left ventricular ejection fraction and Global Longitudinal Strain variability between methodology and experience. *Echocardiography*. 2021;38(4):582—589. doi:10.1111/echo.15025
14. Wang T, Li L, Huang J, Fan L. Assessment of subclinical left ventricle myocardial dysfunction using global myocardial work in type 2 diabetes mellitus patients with preserved left ventricle ejection fraction. *Diabetol Metab Syndr*. 2022;14(1):17. doi:10.1186/s13098-021-00781-x
15. Karlsen S, Dahlslett T, Grenne B. Global longitudinal strain is a more reproducible measure of left ventricular function than ejection fraction regardless of echocardiographic training. *Cardiovasc Ultrasound*. 2019;17(1):18. doi:10.1186/s12947-019-0168-9
16. Herrmann J, Lenihan D, Armenian S, Barac A, Blaes A, Cardinale D, Carver J, Dent S, Ky B, Lyon A R, López-Fernández T, Fradley MG, Ganatra S, Curigliano G, Mitchell JD, Minotti G,

Lang NN, Liu JE, Neilan TG, Nohria A, Valent P. (2022). Defining cardiovascular toxicities of cancer therapies: an International Cardio-Oncology Society (IC-OS) consensus statement, *European Heart Journal*. 2022;43(4);280—299. doi.org/10.1093/eurheartj/ehab674

17. Postadzhiyan A, Andreeva L, Tochev S, Finkov B. Impact of diabetes mellitus on arterial stiffness, and pulsatile hemodynamics in heart failure with preserved ejection fraction. *Journal of Hypertension.* 2023;41(Suppl 3): p e172. doi: 10.1097/01.hjh.0000940632.72210.08

18. Zharikova ES, Villevalde SV, Kobalava ZD. Predictors of adverse left ventricular remodeling in patients after myocardial infarction *RUDN Journal of Medicine*. 2017;21(2):219—226 doi: 10.22363/231302452017212219226 (In Russian). [*Е.С. Жарикова, С.В. Виллевальде, Ж.Д. Кобалава*. Предикторы неблагоприятного ремоделирования левого желудочка у пациентов, перенесших инфаркт миокарда // Вестник РУДН. Серия: Медицина. 2017. Т. 21. № 2. С. 219—226.]

19. Abou R, van der Bijl P, Bax JJ, Delgado V. Global longitudinal strain: clinical use and prognostic implications in contemporary practice. *Heart*. 2020;106(18):1438—1444. doi:10.1136/heartjnl-2019—316215

20. Beautlin A, Govindaraj A, Durgadevi, Uma Maheswari, Yamini «Correlation between diastolic dysfunction and global longitudinal strain imaging in patients with diabetes mellitus.» *Biomedicine*: 2023;43(1):488—491. doi: 10.51248/.v43i01.2378

21. Zhu J, Li W, Chen F, Xie Z, Zhuo K, Huang R. Impact of glycemic control on biventricular function in patients with type 2 diabetes mellitus: a cardiac magnetic resonance tissue tracking study. *Insights Imaging*. 2023;14(1):7. doi:10.1186/s13244-022-01357-7

22. Siripuram C, Mahendran KB, Hegde SV, Murali Krishna S, Suresh Suvarna S, Kandimalla R. Role of Echocardiography in Detecting Left Ventricular Dysfunction Among Diabetic Patients: A Clinical and Biochemical Perspective. *Cureus*. 2025;17(2): e78720. doi:10.7759/cureus.78720

23. Utina TG, Akasheva DU, Korsunsky DV, Drapkina OM. Significance of standard and speckle-tracking echocardiography for early diagnosis of asymptomatic left ventricular dysfunction in type 2 diabetes. *Cardiovascular Therapy and Prevention*. 2023;22(1):3478. doi.org/10.15829/1728-8800-2023-3478. (In Russian). [*Утина Т.Г., Акашева Д.У., Корсунский Д.В., Драпкина О.М.* Значение стандартной и спекл-трекинговой эхокардиографии для ранней диагностики бессимптомной дисфункции миокарда левого желудочка при сахарном диабете 2 типа // Кардиоваскулярная терапия и профилактика. 2023. 22(1). 3478.]

24. Lehner LJ, Haag K, Zhang K. Speckle tracking analysis of left ventricular function in patients with type 1 diabetes mellitus and kidney failure, *European Heart Journal — Cardiovascular Imaging.* 2022;23(Suppl.1): jeab289.060, https://doi.org/10.1093/ehjci/jeab289.060

25. Ifuku M, Takahashi K, Hosono Y, Iso T, Ishikawa A, Haruna H, Takubo N, Komiya K, Kurita M, Ikeda F, Watada H, Shimizu T. Left atrial dysfunction and stiffness in pediatric and adult patients with Type 1 diabetes mellitus assessed with speckle tracking echocardiography. *Pediatric Diabetes*. 2021;22:303—319. doi: 10.1111/PEDI.13141

26. Jensen MT, Sogaard P, Andersen HU, Bech J, Fritz Hansen T, Biering-Sørensen T, Jørgensen PG, Galatius S, Madsen JK, Rossing P, Jensen JS. Global longitudinal strain is not impaired in type 1 diabetes patients without albuminuria: the Thousand & 1 study. *JACC Cardiovasc Imaging*. 2015;8(4):400—410. doi: 10.1016/j.jcmg.2014.12.020

27. Berceanu M, Mirea O, Târtea GC, Donoiu I, Militaru C, Istrătoaie O, Săftoiu A. The Significance of Right Ventricle in Young Subjects with Diabetes Mellitus Type 1. An echocardiographyic study. *Current health sciences journal*. 2019;45:174—178. doi: 10.12865/CHSJ.45.02.07

28. Nemes A, Piros GÁ, Lengyel C, Domsik P, Kalapos A, Várkonyi TT, Orosz A, Forster T. «Complex evaluation of left atrial dysfunction in patients with type 1 diabetes mellitus by three-dimensional speckle tracking echocardiography: results from the MAGYAR-Path Study.» *Anatolian Journal of Cardiology*. 2015;16:587—593. doi: 10.5152/ANATOLJCARDIOL.2015.6225

29. Fridolfsson C, Thegerström J, Åkesson K. Lower left atrial function in young individuals with type 1 diabetes mellitus compared to healthy controls: an echocardiographic study. *Sci. Rep*. 2024;14:3982. doi.org/10.1038/s41598-024-54597-6

30. Ahmed T, Hassan MN, Mazen AA, Hegazy SA. Detection of early left ventricular and left atrial dysfunction in type I diabetes mellitus using two dimensional speckle tracking echocardiography. *The Scientific Journal of Al-Azhar Medical Faculty, Girls.* 2018;2:106—114.

31. Berceanu M, Mirea O, Donoiu I, Militaru C, Săftoiu A, Istrătoaie O. Myocardial Function Assessed by Multi-Layered Two-Dimensional Speckle Tracking Analysis in Asymptomatic Young Subjects with Diabetes Mellitus Type 1. *Cardiology*. 2020;145(2):80—87. doi: 10.1159/000504532

32. Jędrzejewska I, Król W, Światowiec A, Wilczewska A, Grzywanowska-Łaniewska I, Dłużniewski M, Braksator W. Left and right ventricular systolic function impairment in type 1 diabetic young adults assessed by 2D speckle tracking echocardiography. *Eur Heart J Cardiovasc Imaging*. 2016;17(4):438—46. doi: 10.1093/ehjci/jev164

33. Bogdanović J, Ašanin M, Krljanac G, Lalić NM, Jotić A, Stanković S, Rajković N, Stošić L, Rasulić I, Milin J, Popović D, Bogdanović L, Lalić K. Impact of acute hyperglycemia on layer-specific left ventricular strain in asymptomatic diabetic patients: an analysis based on two-dimensional speckle tracking echocardiography. *Cardiovasc Diabetol.* 2019;18(1):68. doi: 10.1186/s12933-019-0876-3

34. Hajdu M, Knutsen MO, Vértes V, Vorobcsuk-Varga N, Molnár G, Wittmann I, Faludi R. Quality of glycemic control has significant impact on myocardial mechanics in type 1 diabetes mellitus. *Sci Rep.* 2022;12:20180 doi.org/10.1038/s41598-022-24619-2

35. Abdel-Salam Z, Khalifa M, Ayoub A, Hamdy A, Nammas W. Early changes in longitudinal deformation indices in young asymptomatic patients with type 1 diabetes mellitus: assessment by speckle-tracking echocardiography. *Minerva Cardioangiol*. 2016;64(2):138—144.

36. Ringle A, Dornhorst A, Rehman MB, Ruisanchez C, Nihoyannopoulos P. Evolution of subclinical myocardial dysfunction detected by two-dimensional and three-dimensional speckle tracking in asymptomatic type 1 diabetic patients: a longterm follow-up study. *Echo Research and Practice*. 2017;4(4):73—81. doi.org/10.1530/ERP-17-0052

37. Li Z, Qian Y, Fan CY, Huang Y. Application of three-dimensional speckle tracking technique in measuring left ventricular myocardial function in patients with diabetes. *World J. Diabetes*. 2024;15(4):783—792. doi: 10.4239/wjd.v15.i4.783

Возможность использования методики спекл-трекинг при проведении эхокардиографии у пациентов с сахарным диабетом: систематический обзор

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Аннотация. Эхокардиография с отслеживанием спеклов, свидетельствует о заметном прогрессе в области неинвазивной визуализации сердца, облегчающей оценку деформации миокарда в различных пространственных плоскостях. Этот инновационный метод превосходит традиционные эхокардиографические показатели, такие как фракция выброса левого желудочка, и позволяет выявлять субклиническую дисфункцию миокарда на ранних стадиях. Особое внимание уделяется значению глобальной продольной деформации (GLS) как высокочувствительного биомаркера, указывающего на раннюю систолическую недостаточность, Клиническая значимость оценки субклинической дисфункции миокарда особенно выражена у лиц с сахарным диабетом 1 типа (СД1). Эта демографическая группа характеризуется повышенной склонностью к развитию сердечно-сосудистых осложнений. Многочисленные исследования показывают, что STE позволяет выявлять аномалии деформации миокарда у пациентов с диабетом задолго до появления явных сердечных проявлений или снижения уровня ЛВЭФ. Это способствует своевременному выявлению диабетической кардиомиопатии, улучшает мониторинг терапевтических реакций и позволяет проводить стратификацию рисков на основе таких показателей, как уровень ГЛС и предсердное напряжение. *Выводы*: Спекл трекинг эхокардиография становится незаменимым инструментом в современной кардиологии, особенно для пациентов с диабетом, поскольку они позволяют выявить нюансы дисфункции миокарда, часто упускаемые из виду традиционными методами. Тем не менее, дополнительные проспективные исследования, ориентированные на результаты, необходимы для обоснования прогностической значимости препарата и его эффективного внедрения в стандартную клиническую практику.

Ключевые слова: спэкл трэкинг эхокардиография, глобальная продольная деформация миокарда, диабетическая кардиомиопатия, субклиническая дисфункция миокарда

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