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Acute hyperglycaemia is associated with a left ventricular mechanical phenotype resembling acute myocardial ischemia: a comparative speckle-tracking echocardiography study

Gordana Krljanac
University of Belgrade
Milika Ašanin
University of Belgrade
Jelena Bogdanović
University of Belgrade
Lidija Savić
University of Belgrade
Sandra Singh Lukač
University of Belgrade
Sanja Stanković
University Clinical Center of Serbia
Iva Rasulić
University of Belgrade
Ljiljana Popović
University of Belgrade
Marija Polovina
University of Belgrade
Ana Petakov
University Clinical Center of Serbia
Dušanka Lukić
University Clinical Center of Serbia
Jordan Avramović
University Clinical Center of Serbia
Aleksandra Jotić
University of Belgrade
Nebojša M. Lalić
University of Belgrade

Katarina Lalić

katarina.s.lalic@gmail.com

University of Belgrade

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Abstract

This study was aimed to compare LV structural, functional, and mechanical characteristics of acute hyperglycaemia (≥ 11.1 mmol/L) in patients with diabetes mellitus (DM) without cardiovascular diseases (CVD) (group A, n = 52) and of acute myocardial ischemia (AMI) in patients without DM (group D, n = 55) using two-dimensional speckle-tracking echocardiography (2D-STE). Comparison groups included patients with well-controlled DM without complications (Group B, n = 20) and healthy controls (Group C, n = 20). We found that LV global longitudinal strain (GLS), as well as global circumferential strain (GCS) was comparably reduced in both groups A (-18.47+/-1.50% and − 19.86 ± 2.80%) and D (-17,21+/-3,35% and − 18.79 ± 3.40%) being significantly lower in comparison to groups B and C. Longitudinal mechanical dispersion index (LMDI) was highest in Group D and was significantly increased compared with Group A while circumferential MDI was equally increased in both groups A and D in comparison to control groups. Similar deterioration in peak apical rotation, LV twist and torsion were observed in both groups A and D. Simultaneously, AMI was associated with more pronounced LV remodelling in comparison to other three groups. In conclusion, acute hyperglycaemia alone induces LV mechanical dysfunction resembling AMI, affecting myocardial deformation and rotational mechanics despite the absence of overt CVD.

Introduction

Acute hyperglycaemia is increasingly recognized as an important contributor to adverse cardiovascular outcomes, even in individuals without previously diagnosed diabetes mellitus (DM). Experimental and clinical studies have demonstrated that transient hyperglycaemia induces oxidative stress, endothelial dysfunction, inflammation, and impaired coronary microvascular function, all of which may adversely affect myocardial performance [1]. In patients with acute myocardial infarction (AMI), stress hyperglycaemia is associated with larger infarct size, a higher incidence of the no-reflow phenomenon, heart failure, and increased mortality, irrespective of pre-existing diabetes [2].

Acute myocardial ischemia produces characteristic alterations in left ventricular (LV) mechanics that can be detected using speckle-tracking echocardiography (STE). Reduced longitudinal and circumferential myocardial strain, impaired rotational mechanics, and increased mechanical dispersion reflect the regional heterogeneity of myocardial contraction and provide sensitive markers of ischemic myocardial dysfunction beyond conventional measures such as left ventricular ejection fraction (LVEF) [3].

Accumulating evidence suggests that acute hyperglycaemia may also impair LV function in patients with type 2 diabetes, even in the absence of overt cardiovascular disease (CVD) [4]. In our previous study, asymptomatic patients with acute hyperglycaemia and preserved LVEF exhibited significant impairment of global and multilayer myocardial deformation, particularly global longitudinal strain (GLS), despite the absence of structural heart disease. Importantly, these abnormalities persisted despite subsequent improvement in glycaemic control, suggesting that episodes of acute hyperglycaemia may induce myocardial alterations that are not entirely reversible [5].

Whether acute hyperglycaemia alone produces myocardial mechanical alterations resembling those observed during acute myocardial ischemia has not been systematically investigated. This study was aimed to compare LV structural, functional, and mechanical characteristics of acute hyperglycaemia in patients with DM without CVD and of acute myocardial ischemia in patients without DM using comprehensive speckle-tracking echocardiography.

Methods

Study design and population

This single-center observational study was conducted at the University Clinical Center of Serbia (UCCS), Belgrade, Serbia, between January 2014 and January 2018. The study was designed to compare LV structural, functional, and mechanical characteristics in patients with acute hyperglycaemia without CVD and those with acute myocardial ischaemia using comprehensive speckle-tracking echocardiography.

A total of 147 participants were enrolled and allocated into four study groups.

Group A comprised 52 consecutive patients with diabetes, 23 with type 1 diabetes (T1D) and 29 with type 2 diabetes (T2D), both gender, with mean age 39.2 ± 13.1 years, admitted to the Intensive Care Unit (ICU) of the Clinic for Endocrinology, Diabetes and Metabolic Diseases, UCCS because of acute hyperglycemia, defined as a plasma glucose concentration ≥11.1 mmol/L at hospital admission. Patients were eligible if they fulfilled all of the following criteria: (1) previously diagnosed DM or newly diagnosed DM according to the American Diabetes Association diagnostic criteria applicable at the time of enrolment; (2) plasma glucose concentration ≥11.1 mmol/L at admission; (3) absence of previously known or newly diagnosed CVD, including arterial hypertension; and (4) absence of diabetic microvascular complications, including diabetic retinopathy, nephropathy, or neuropathy.

Patients younger than 18 years or older than 65 years were excluded, as were those with heart failure, arterial hypertension, malignant disease, chronic obstructive pulmonary disease, hepatic insufficiency, renal dysfunction (estimated glomerular filtration rate ≤60 mL/min/1.73 m²), acute or chronic infection, diabetic ketoacidosis, or treatment with corticosteroids or immunosuppressive agents.

Three comparison groups were included.

Group B consisted of 20 patients with DM and optimal metabolic control (mean age 44.0 ± 15.4 years), defined as HbA1c ≤7.0% and fasting plasma glucose <7.0 mmol/L, without clinically evident macrovascular or microvascular diabetic complications.

Group C comprised 20 healthy volunteers (mean age 35.1 ± 10.5 years) without DM or CVD.

Group D included 55 consecutive patients (mean age 52.9 ± 6.1 years) admitted to the Coronary Care Unit (CCU) of the Clinic for Cardiology UCCS with acute ST-segment elevation myocardial infarction (STEMI) who underwent successful primary percutaneous coronary intervention (PPCI). To ensure

comparability with Group A, only patients with preserved LV systolic function (left ventricular ejection fraction [LVEF] >50%), no previous history of myocardial infarction, and without significant comorbidities affecting myocardial function were included.

Study protocol

The study protocol was approved by the Institutional Ethics Committee and all participants provided written informed consent before enrolment. The study was conducted in accordance with the principles of the Declaration of Helsinki.

For patients with acute hyperglycaemia (Group A), demographic and clinical characteristics, medical history, and anthropometric measurements were obtained immediately after hospital admission. Venous blood samples were collected before initiation of antihyperglycemic therapy. Comprehensive transthoracic echocardiography was subsequently performed before administration of any glucose-lowering treatment.

Participants in Groups B and C underwent clinical assessment, anthropometric measurements, laboratory testing, and echocardiographic examination during outpatient evaluation.

Patients with acute STEMI (Group D) underwent clinical assessment and laboratory testing on admission, followed by comprehensive echocardiographic examination, including myocardial deformation analysis, 5 ± 2 days after successful PPCI when clinically stable.

Conventional echocardiography examination

Comprehensive transthoracic echocardiography was performed using a commercially available ultrasound system (Vivid E9, GE Healthcare, Horten, Norway) equipped with a 3.5-MHz phased-array transducer.

Standard two-dimensional (2D), M-mode, colour Doppler, pulsed-wave Doppler, continuous-wave Doppler, tissue Doppler imaging, and two-dimensional speckle-tracking echocardiography (2D-STE) were performed according to the recommendations of the American Society of Echocardiography (ASE) and the European Association of Cardiovascular Imaging (EACVI) [6–11].

Left ventricular end-diastolic volume (LVEDV) and end-systolic volume (LVESV) were calculated using the modified biplane Simpson method, and LVEF was derived accordingly. Left ventricular mass index (LVMI) was calculated using ASE-recommended equations.

Assessment of LV diastolic function included transmitral inflow velocities (E and A waves), tissue Doppler-derived septal and lateral e' velocities, average E/e' ratio, and left atrial volume index (LAVI), according to current ASE/EACVI recommendations.

Two-dimensional speckle-tracking echocardiography

Left ventricular myocardial mechanics were assessed using two-dimensional speckle-tracking echocardiography (2D-STE).

Images were acquired at frame rates ranging from 50 to 70 frames/s and analysed offline using dedicated software (EchoPAC version 203, GE Healthcare). Only image loops with adequate image quality and satisfactory myocardial tracking were included in the analysis.

Global longitudinal strain (GLS) was calculated using the standard 18-segment LV model. Global circumferential strain (GCS), basal and apical rotation, LV twist, LV torsion, and longitudinal mechanical dispersion were measured according to current consensus recommendations [6,8,12].

Longitudinal mechanical dispersion was defined as the standard deviation of the time-to-peak longitudinal strain across the 18 LV segments.

As in our previous study [5], to assess intra-observer reproducibility, myocardial deformation analysis was repeated in 15 randomly selected participants 2–4 weeks after the initial analysis by the same investigator (G.K.). Reproducibility was evaluated using the interclass correlation coefficient (ICC) together with the absolute percentage difference between repeated measurements.

Laboratory analyses

Plasma glucose concentrations were measured using a commercial assay (Abbott Diagnostics). Glycated haemoglobin (HbA1c) was determined by spectrophotometry (Sebia, France).

Serum total cholesterol, high-density lipoprotein cholesterol (HDL-C), and triglycerides were measured enzymatically (ADVIA Chemistry), whereas low-density lipoprotein cholesterol (LDL-C) was calculated using the Friedewald equation.

Cardiac biomarkers, including cardiac troponin (Roche Diagnostics) and N-terminal pro-B-type natriuretic peptide (NT-proBNP; Abbott Diagnostics), were determined using commercially available chemiluminescent immunoassays.

Statistical analysis

Continuous variables are presented as mean ± standard deviation (SD) or median (interquartile range), depending on data distribution, whereas categorical variables are presented as frequencies and percentages.

Normality of data distribution was assessed using the Shapiro–Wilk test. Comparisons among the four study groups were performed using one-way analysis of variance (ANOVA) followed by Bonferroni post hoc correction for normally distributed variables or the Kruskal–Wallis test for non-normally distributed variables. Categorical variables were compared using the χ^2 test or Fisher's exact test, as appropriate.

Sample size was estimated *a priori* based on previously published data, assuming statistical power of 80% and type I error probability 0.05, yielding a minimum required sample size of 133 participants.

All statistical analyses were performed using SPSS Statistics version 20.0 (IBM Corp., Armonk, NY, USA). All tests were two-sided, and a *p* value <0.05 was considered statistically significant.

Results

Characteristics of the study population

Baseline demographic and anthropometric characteristics of the investigated groups are presented in Table 1. There were no significant differences among groups regarding sex distribution and body mass index (BMI). Patients in Group D were significantly older compared with subjects from the other groups (p<0.001). The duration of DM was comparable between Groups A and B, as well as proportion of patients with T1D and T2D among those groups (44.2% and 55.8% in Group A vs 40% and 60% in Group B, p=ns). Analysis of previous antidiabetic treatment revealed a similar pattern of medication use between diabetic groups, including oral antidiabetic drugs and insulin therapy.

None of the subjects in Groups A, B, or C were receiving cardiovascular medications.

Laboratory analyses

Biochemical characteristics of the study groups are summarized in Table 1. Plasma glucose concentrations were significantly higher in Group A compared with Groups B, C, and D (p<0.001 for all comparisons). Similarly, HbA1c levels were significantly elevated in Group A compared with both diabetic patients with euglycaemia (Group B) and healthy controls (Group C) (p<0.001 for both comparisons). HbA1c was not analysed in Group D because these patients were included during acute ischemic presentation without known DM.

Regarding the analysis of lipid parameters, HDL cholesterol levels were significantly lower in Groups A and D compared with healthy controls (Group C; p=0.01). LDL cholesterol levels were significantly higher in Group D compared with Groups A, B, and C (p=0.007, p=0.001, and p=0.009, respectively). Triglyceride concentrations were significantly elevated in Group A compared with all other groups (p=0.007) (Table 1).

Simultaneously, markers of myocardial injury and cardiac stress were significantly increased in Group D. Troponin and NT-proBNP concentrations were significantly higher in Group D compared with Groups A, B, and C (p<0.001 for all comparisons). No significant differences in troponin or NT-proBNP levels were observed among Groups A, B, and C (Table 1).

Conventional structural and systolic echocardiographic parameters of the left ventricle

Conventional echocardiographic parameters of LV systolic function are presented in Table 2. LV mass index (LVMI) was significantly higher in Group D compared with Groups A, B, and C ($p<0.001$), indicating the most pronounced LV remodelling in this group. Similarly, LV end-diastolic volume (EDV), end-diastolic volume index (EDVI), end-systolic volume (ESV), and end-systolic volume index (ESVI) were significantly increased in Group D, whereas LVEF was significantly reduced compared with the remaining groups.

No significant differences in these conventional systolic parameters were observed among Groups A, B, and C (Table 2).

Conventional diastolic echocardiographic parameters of the left ventricle

Assessment of LV diastolic function using pulsed-wave Doppler at the mitral valve demonstrated significantly lower transmitral E-wave velocity and E/A ratio in both diabetes groups (A and B) and in Group D compared with healthy controls (Group C). Additionally, significant differences in these parameters were observed between Groups A and D, whereas no significant differences were detected between the two diabetes groups (A and B) suggesting early diastolic dysfunction in patients with diabetes despite preserved glycaemic control. (Table 2).

Tissue Doppler analysis demonstrated marked impairment of LV relaxation, particularly in Group D, characterized by reduced lateral and septal e' velocities. Similar alterations were also observed in Group A. No significant differences in e' velocity or E/e' ratio were observed between Groups A and D; however, both parameters differed significantly between Groups A and C and between Groups A and B (Table 2). In contrast, no significant differences were observed between Groups B and C.

Analysis of left atrial parameters revealed the highest left atrial volume (LAV) and left atrial volume index (LAVI) values in Group A. No significant differences in LAV or LAVI were observed between Groups A and D or between Groups A and B. However, both parameters were significantly higher in Group A compared with healthy controls (Group C). Differences were also observed between Groups B and C (Table 2).

Left ventricular speckle-tracking analysis

Global longitudinal strain (GLS)

Speckle-tracking analysis revealed significant impairment of LV global longitudinal strain (GLS) in Group D (−17.21±3.35%), representing the most reduced values among the investigated groups. Interestingly, LV GLS in Group D was comparable with that observed in Group A (patients with DM and acute hyperglycaemia; −18.47±1.50%; p=NS) (Table 3, Figures 1 and 3).

LV GLS in Group A was significantly reduced compared with Group B (patients with DM and euglycaemia; −20.79±1.91%; p=0.004) and healthy controls (Group C; −22.00±1.85%; p<0.001) (Table 3, Figures 1 and 3).

Longitudinal mechanical dispersion index (LMDI) was highest in Group D (acute myocardial ischaemia) and was significantly increased compared with Group A (acute hyperglycaemia) and other controls groups B and C (Table 3, Figure 2). No significant differences in LMDI were observed between Groups A and B or between Groups A and C (Table 3, Figures 2 and 3).

Global circumferential strain (GCS)

Global circumferential strain (GCS) was significantly impaired in Group D compared with Groups B and C. Additionally, GCS values in Group A were significantly different compared with Groups B and C (Table 3, Figure 1). Similar to GLS findings, GCS values did not significantly differ between Groups A (−19.86±2.80%) and D (−18.79±3.40%; p=NS).

In contrast to LMDI, circumferential mechanical dispersion index (CMDI) showed comparable values between Groups A (acute hyperglycaemia) and D (acute myocardial ischaemia). However, CMDI was significantly increased in both Groups A and D compared with Groups B and C (Table 3, Figure 2).

Left ventricular twist and torsion

The lowest values of LV twist and torsion were observed in Group D, but no significant differences were detected between Groups A and D regarding these parameters (Table 3, Figure 3). Reduced LV twist in Group A was mainly related to impaired peak global (G) apical rotation, which was similarly reduced in Group D. In contrast, no significant differences in peak G basal rotation were observed among the investigated groups (Table 3).

Reproducibility analysis

The intra-observer variability for longitudinal and circumferential strain was 4.3% and 5.2% (respectively). ICC for intra-observer variability of the corresponding values was 0.898 (95% CI 0.606–0.971; p < 0.001) and 0.724 (95% CI 0.218–0.912; p < 0.01).

Discussion

The main finding in our study is that two different acute events, hyperglycaemia and myocardial ischemia, are associated with more similar than different impairment of LV myocardial mechanics, even if the LVEF are preserved. Using 2D-STE, we demonstrated that acute hyperglycaemia and acute myocardial ischemia were associated with a comparable degree of impairment in global myocardial

deformation, including reduced LV GLS and GCS. However, the pattern of mechanical abnormalities differed between these conditions, as acute ischemia was characterized by greater longitudinal mechanical dispersion, suggesting increased regional heterogeneity of myocardial contraction. These findings indicate that acute metabolic disturbances may induce profound but potentially distinct alterations in myocardial mechanics, which remain undetected by conventional echocardiographic parameters. A summary of similarities and differences between acute hyperglycaemia and acute myocardial ischemia regarding echocardiographic markers of myocardial function is presented in Table 4.

The effects of acute hyperglycaemia versus acute myocardial ischemia on LV function: conventional echocardiography

LV structural and systolic function

First, as expected, using conventional echocardiography we detected significant LV deformation (remodelling) in patients with acute ischaemia. These findings were significantly different compared with both diabetes patients with euglycaemia and healthy controls, as well as compared with patient presenting with acute hyperglycaemia (Table 2). Importantly, patients with acute hyperglycaemia exhibited preserved LV ejection fraction (LVEF), suggesting that conventional echocardiography may have limited sensitivity for detecting early myocardial dysfunction associated with acute metabolic disturbances.

These findings emphasize the importance of advanced echocardiographic techniques, particularly STE, for identifying subtle abnormalities in myocardial performance that may precede changes in LVEF.

LV diastolic function

In contrast to conventional systolic parameters, tissue Doppler measurements revealed significant abnormalities of LV diastolic function in patients with acute hyperglycaemia. Early diastolic mitral annular velocity (e') and average E/e' ratio were comparable between patients with acute hyperglycaemia and those with acute ischemia, and both groups differed significantly from diabetic patients with euglycaemia and healthy controls. These findings suggest that acute hyperglycaemia may contribute to an additional deterioration of LV relaxation properties, with an effect comparable to that observed during acute ischemic stress.

Similarly, left atrial volume (LAV) and left atrial volume index (LAVI), which reflect chronic elevation of LV filling pressures, were increased in patients with acute ischemia as well as in both diabetic groups compared with healthy controls. This finding suggests that diabetes itself is associated with persistent alterations in LV filling conditions, independent of the presence of acute hyperglycaemia.

These observations are consistent with previous studies demonstrating that individuals with diabetes may exhibit impaired diastolic function despite preserved systolic function, reflecting early diabetic myocardial involvement [7,13,14]. Importantly, diastolic abnormalities have been described even in asymptomatic patients with newly diagnosed diabetes or prediabetes, suggesting that metabolic disturbances associated with diabetes may negatively influence myocardial relaxation independently of other cardiovascular risk factors [15]. Furthermore, several studies have demonstrated an association between increasing HbA1c levels and worsening diastolic function in individuals with type 2 diabetes, including the development of restrictive filling patterns [16].

Several mechanisms may explain the observed abnormalities in patients with acute hyperglycaemia. Previous experimental studies have demonstrated that acute hyperglycaemia may increase cardiomyocyte resting tension and myocardial stiffness [17]. Enhanced formation and deposition of advanced glycation end products (AGEs), increased extracellular matrix cross-linking, fibrosis, and impaired myocardial compliance have been proposed as potential contributors to diabetic myocardial dysfunction [18]. In addition, LV diastolic impairment may be related to coronary microvascular dysfunction [19], altered myocardial metabolism, insulin resistance, and impaired glucose regulation [20]. The comparable degree of diastolic impairment observed between hyperglycaemic and ischemic patients in our study supports the concept that acute metabolic stress can rapidly affect myocardial relaxation and filling properties.

The effects of acute hyperglycaemia versus acute myocardial ischemia on LV function: 2D-STE

In the present study, we used 2D-STE to provide a detailed assessment of LV myocardial mechanics in diabetes patients with acute hyperglycaemia and in non-diabetic patients presenting with acute myocardial ischemia. The principal finding was that acute hyperglycaemia was associated with a degree of impairment in LV systolic deformation comparable to that observed in acute ischemia, despite the absence of overt abnormalities on conventional echocardiography. These findings suggest that acute metabolic disturbances may rapidly influence myocardial mechanics and that STE may provide clinically relevant information beyond LVEF assessment.

Global LV systolic deformation

LV GLS is considered one of the most sensitive echocardiographic markers of early myocardial dysfunction, particularly reflecting abnormalities of subendocardial longitudinal fibers, which are highly susceptible to ischemic and metabolic injury [22,23]. In our study, the magnitude of GLS reduction was similar in patients with acute hyperglycaemia and acute ischemia, suggesting that acute hyperglycaemia may induce substantial impairment of longitudinal myocardial deformation to an extent comparable to ischemia.

This finding is consistent with previous experimental and clinical observations demonstrating that acute hyperglycaemia promotes oxidative stress [24], reduces nitric oxide bioavailability, alters myocardial energy metabolism, and affects intracellular calcium handling, all of which may negatively influence cardiomyocyte contractility [25,26]. Therefore, the reduction in GLS observed in hyperglycaemic patients may reflect an early manifestation of metabolic myocardial injury occurring before changes in conventional systolic parameters become apparent.

Similarly, the comparable reduction in LV GCS observed in both groups indicates involvement of circumferential myocardial fibers. Although longitudinal deformation is generally considered the earliest marker of myocardial dysfunction, circumferential mechanics contribute substantially to maintenance of LV systolic performance, particularly when longitudinal function is impaired [27].

Mechanical dispersion and myocardial synchrony

Despite similar abnormalities in global deformation parameters, mechanical dispersion analysis revealed important differences between acute hyperglycaemia and acute ischemia. Longitudinal mechanical dispersion (LMD) was more pronaunced in patients with acute ischemia, whereas circumferential mechanical dispersion (CMD) did not differ between groups A and D.

Mechanical dispersion reflects heterogeneity in myocardial contraction timing and has been associated with regional ischemia, myocardial fibrosis, scar formation, and increased arrhythmogenic risk [28–30]. The greater LMD observed in acute ischemia is consistent with the regional nature of ischemic injury, where heterogeneous reduction in myocardial perfusion leads to delayed and asynchronous contraction of affected segments.

In contrast, acute hyperglycaemia appears to induce a more diffuse alteration of myocardial mechanics, characterized by reduced deformation magnitude but relatively preserved contraction synchrony. This distinction is clinically relevant because global strain parameters alone may identify the presence of myocardial dysfunction but may not provide sufficient information regarding its underlying mechanism. Therefore, mechanical dispersion parameters may offer additional diagnostic value by helping differentiate focal ischemic myocardial injury from a more homogeneous metabolic myocardial impairment.

LV rotational mechanics, twist, and torsion

Both acute hyperglycemia and acute ischemia were associated with comparable impairment of LV rotational mechanics, including reduced LV twist and torsion. These abnormalities were primarily driven by decreased peak apical rotation, whereas peak basal rotation remained relatively preserved.

LV twist results from the coordinated opposite-direction rotation of the apex and base and represents an important component of LV systolic efficiency and diastolic recoil [31]. Apical rotation is particularly

sensitive to myocardial injury because of differences in fiber architecture, regional loading conditions, and potential susceptibility to metabolic and microvascular disturbances [32].

The selective reduction in apical rotation observed in both groups suggests that acute metabolic and ischemic stress may share common effects on myocardial rotational mechanics. Preservation of basal rotation may represent an early compensatory mechanism aimed at maintaining overall LV systolic performance during acute stress.

Our findings are consistent with previous observations demonstrating an association between poor glycaemic control and impaired LV rotational mechanics. HbA1c levels have been negatively correlated with apical and global LV rotation in patients with diabetes, indicating that chronic metabolic dysregulation may adversely affect myocardial mechanics [33]. Furthermore, peak apical rotation assessed by 2D-STE has been proposed as a sensitive marker of early LV dysfunction in asymptomatic individuals with diabetes [34].

The similarity in rotational abnormalities between the two groups further supports the concept that acute metabolic stress (as hyperglycaemia) can mimic ischemia-like alterations in LV mechanics, a finding that may have important diagnostic and prognostic implications.

Clinical implications

Stress hyperglycemia has consistently been associated with adverse outcomes in patients with acute coronary syndromes and other acute cardiovascular conditions, including individuals without previously diagnosed diabetes [35]. The findings of our study provide a potential mechanistic explanation for this association by demonstrating that acute hyperglycaemia is accompanied by measurable impairment of LV deformation and rotational mechanics, even when LVEF remains preserved.

Importantly, while global deformation abnormalities were comparable between acute hyperglycaemia and acute ischemia, differences in mechanical dispersion suggests that **advanced 2D-STE parameters may provide additional value in distinguishing ischemic myocardial injury from metabolic myocardial dysfunction**. In acute clinical settings, where troponin elevation, electrocardiographic abnormalities, and symptoms may have overlapping or non-specific presentations, STE-derived parameters may contribute to improved characterization of myocardial injury.

Research limitations

Several limitations should be acknowledged. First, the observational design and relatively small sample size limit the ability to establish causal relationships between acute hyperglyacemia and myocardial dysfunction. Nevertheless, all participants were carefully selected and groups were comparable regarding relevant clinical characteristics. Second, longitudinal follow-up was not performed; therefore, we cannot determine whether the observed abnormalities in myocardial mechanics are reversible after

correction of hyperglycaemia or resolution of ischemia. However, in our previous study [5], changes in LV systolic function during acute hyperglycaemia were not reversible after short-term period (3 months) with good glycemic control. Future long-term studies including serial STE assessment after metabolic stabilization would provide important insights into the dynamic nature of these changes. Third, direct assessment of myocardial perfusion, metabolism, fibrosis, or microvascular function was not performed. The combination of STE with cardiac magnetic resonance imaging, including tissue characterization and perfusion assessment, may further clarify the mechanisms responsible for hyperglycaemia-associated myocardial dysfunction.

Finally, all echocardiographic analyses were performed offline using EchoPAC version 203 (GE Medical Systems). Although this software is widely used for STE analysis, two-dimensional imaging-based techniques have inherent methodological limitations, including dependence on image quality and potential variability related to vendor-specific algorithms.

Conclusions

Acute hyperglycaemia is associated with significant impairment of LV myocardial mechanics comparable to that observed in acute myocardial ischemia, affecting global myocardial deformation and rotational mechanics, including reduced LV GLS, GCS, twist and torsion.

However, acute ischemia is characterized by greater longitudinal mechanical dispersion, reflecting increased regional heterogeneity of myocardial contraction. These findings suggest that acute metabolic disturbances may produce substantial but distinct alterations in myocardial function and highlight the potential role of advanced echocardiographic analysis in identifying and characterizing early myocardial dysfunction in patients with diabetes and acute cardiovascular stress.

Abbreviations

2D-STE: two-dimensional speckle tracking echocardiography; AMI: acute myocardial infarction; BMI: body mass index; CCU: coronary care unit; Ch: cholesterol; CMDI: circumferential mechanical dispersion index; CVD: cardiovascular disease; DM: diabetes mellitus; EDV: end-diastolic volume; EDV: end-diastolic volume; EDVI: end-diastolic volume index; EF: ejection fraction; ESV: end-systolic volume; ESV: end-systolic volumes; ESVI: end-systolic volume index; GCS: global circumferential strain; GLS: global longitudinal strain; ICC: interclass correlation coefficient; ICU: Intensive Care Unit; LAV: left atrium volume; LAVI: left atrium volume index; LMDI: longitudinal mechanical dispersion index; LV: left ventricle; MDI: mechanical dispersion index; NT-proBNP: N terminal brain fragment (B-type) for natriuretic peptide; PPCI: primary percutaneous coronary intervention; STEMI: ST-segment elevation myocardial infarction; T1D: type 1 diabetes; T2D: type 2 diabetes; UCCS: University Clinical Center of Serbia.

Declarations

Acknowledgements

Not applicable

Authors' contributions

Conceptualization: KL, GK, NML, MA; Design the study, and analyse the data: KL, AJ, NML, GK, LS, JB, SSL, IR; Wrote the manuscript: KL, GK, JA, DL, JB; Data curation: SS, LJP, MP, AP, JA, DL; Formal analysis: MA, GK, KL, NML, MP, AP; Visualization and echocardiography: GK; Performed biochemistry analyses SS; Review and editing: KL. MA, NML. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets generated and analysed for this study are available from the corresponding author upon reasonable request.

Ethics approval and consent to participate

The local Ethics Committee of the Faculty of Medicine University of Belgrade approved this study (approval number 29/II-15). Informed consent was obtained from all investigated subjects before enrolment.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Tables

Tables 1 to 4 are available in the Supplementary Files section.

Figures

Figure 1.

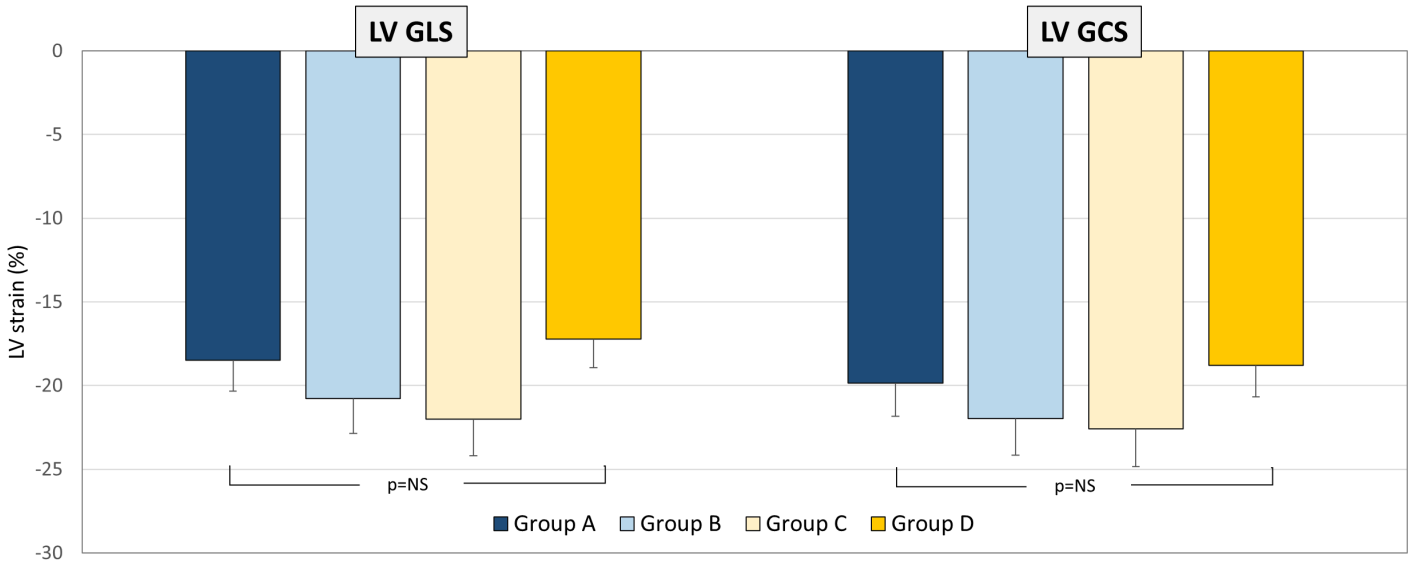


Figure 1

Comparison of left ventricle (LV) global longitudinal strain (GLS) and global circumferental strain (GCS) in diabetes patients with acute hyperglycaemia (*Group A*), in diabetes patients with euglycemia (*Group B*), in healthy controls (*Group C*) and in non-diabetes patients with scute myocardial ischemia (*Group D)*.

Figure 2.

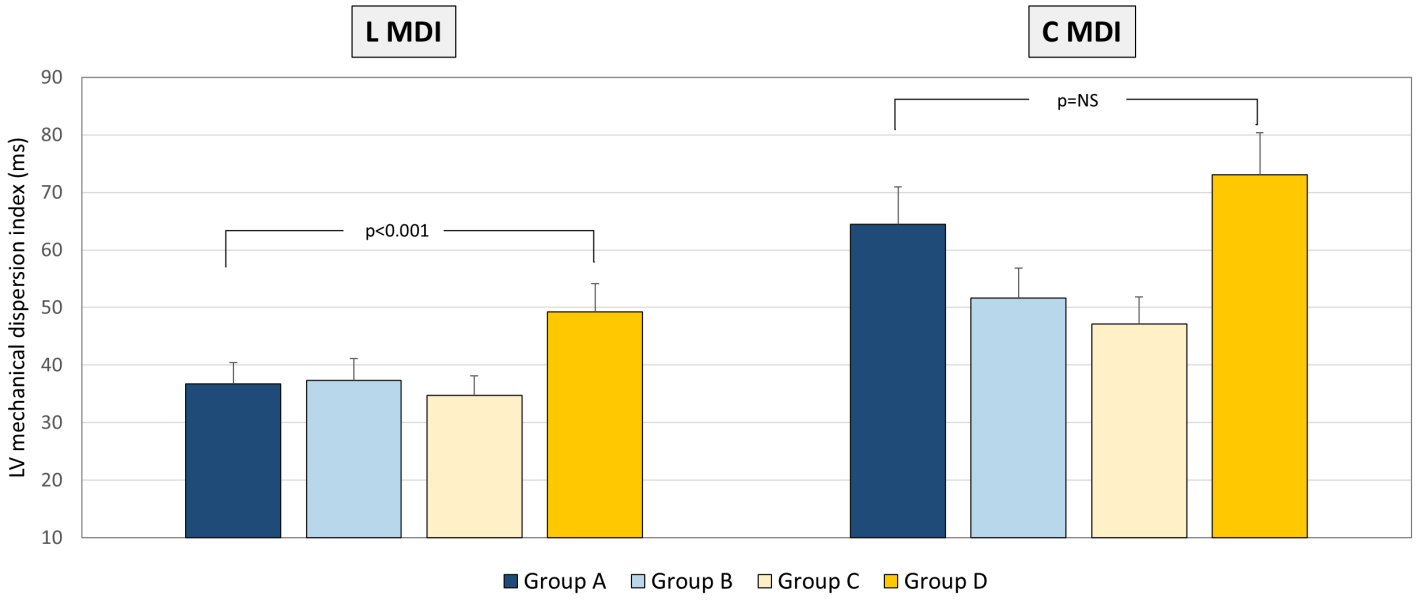


Figure 2

Comparison of longitudinal mechanical dispersion index (L MDI) and circumferental mechanical dispersion index (C MDI) in diabetes patients with acute hyperglycaemia (*Group A*), in diabetes patients with euglycemia (*Group B*), in healthy controls (*Group C*) and in non-diabetes patients with acute myocardial ischemia (*Group D)*.

Figure 3.

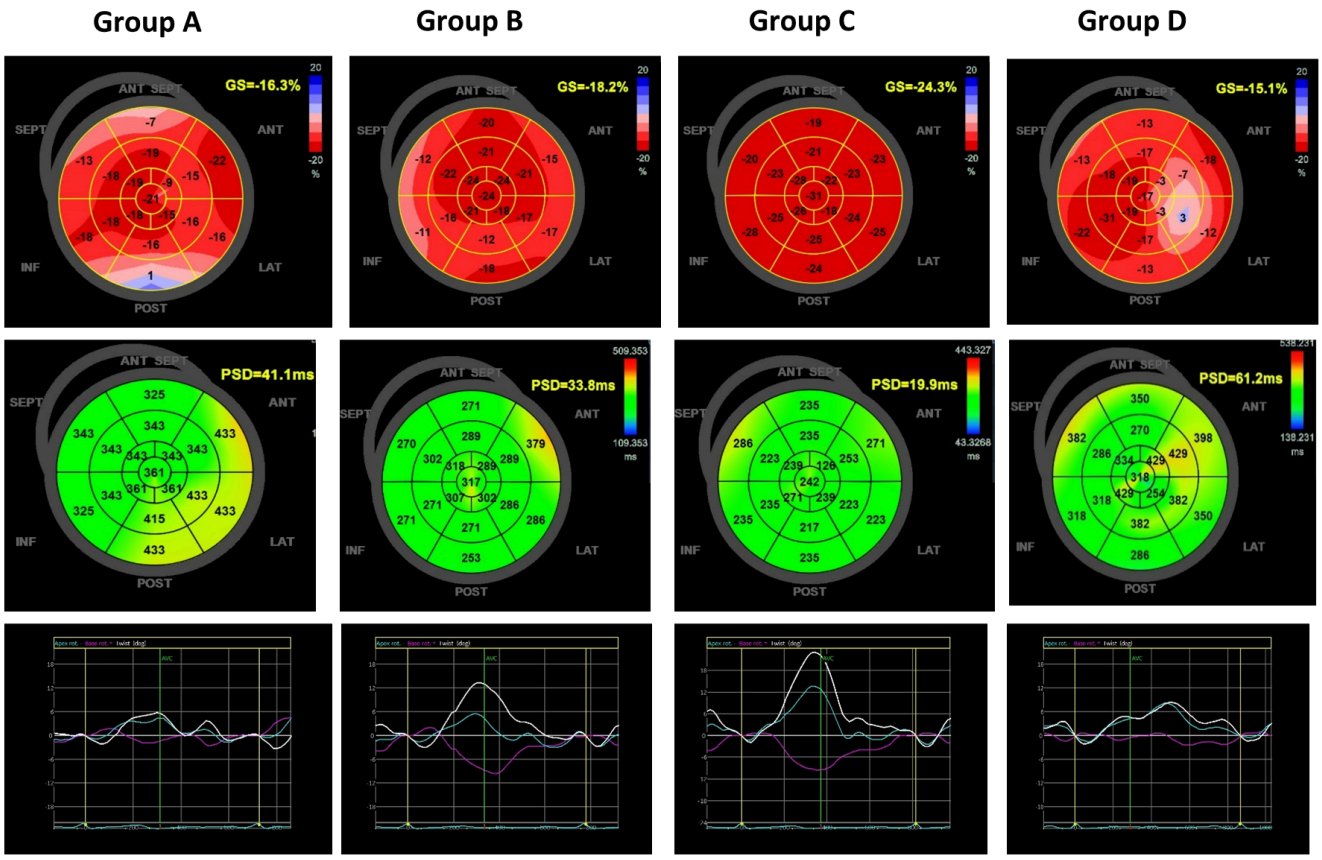


Figure 3

In this picture are presented examples of GLS bulls-eye maps in the first row, MDI maps in the second row, and twist curves in the third row for representative diabetes patient with acute hyperglycaemia (*Group A*), diabetes patient with euglycemia (*Group B*), healthy control subject (*Group C*) and non-diabetes patient with acute myocardial ischemia (*Group D)*. GLS: global longitudinal strain; MDI: mechanical dispersion index.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table1to4.docx